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STEAM GENERATION
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Fuels and combustion—a 32-page special section 57

Figuring combustion ... 58
Chemical ABC's 61
How to figure volumes .. 62
Working by analysis 66
The solid fuels 68
Coal-producing map 72
Table of typical analyses 73
Table of coal shipments . 74
Map of market areas ... 75
Liquid, gaseous fuels ... 76
Fuels in action 78
Fuel-bed firing 80
Burner firing 82
Smoke, flyash, cinder ... 84
Which fuel? 85
Fuel selection 87

Photopage—new outdoor boiler at Wood River, Illinois .. 89
Testing bypass valves at Boulder Dam hydroelectric plant . 92
Reminiscences about the Old Chief—second in a series .. 93
Four years operating experience with a slag-tap furnace . 94
Back to air injection?—looking into the diesel future 96
How to engineer V-Belts to suit the particular drive 98
What is adequate protection for electrical circuits? 116
Watch these dangerous fire hazards in your power plant .. 118

THE OPERATING ENGINEER

Brazed lap seams are strong if they are made right 101
Results at Factory 4 show high boiler efficiency 103
Practical Aids 104
Argument Corner 108
Readers' Problems 109
How to V-Butt Weld ... 112

OTHER DEPARTMENTS

Power Lines 122
Data Sheet No. 101 128
Engineers' Bookshelf 130
George Edwards 132

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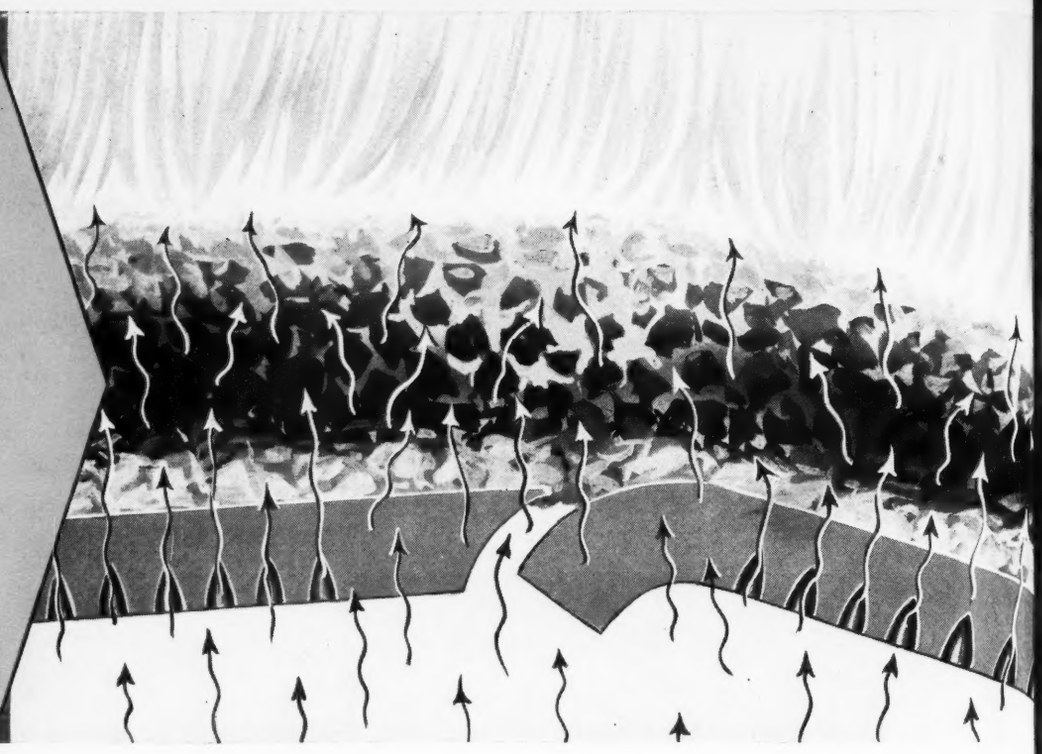
The AIR FLOW of

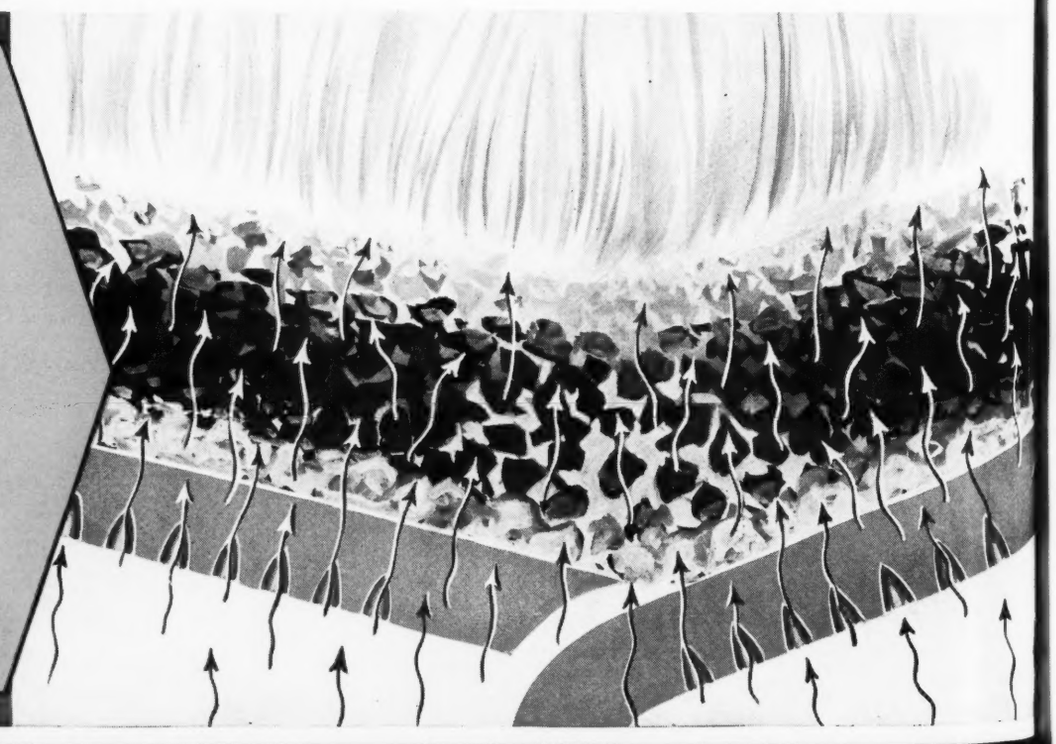
GRATES UP

Opens up fuel bed—lets air through—promotes combustion—keeps grates cool.



GRATES DOWN

Fuel bed cracks—limits size of clinker formation.



Westinghouse

Established 1882 POWER Philip W Swain, Editor

Fuels and Combustion

NUMBER THIRTY-THREE in POWER'S series of special sections, this one tells how to buy and burn fuels and how to figure their combustion—in all, 32 pages of practical information on fuel selection and burning.

"How to Figure Combustion", the first division, breaks precedent by giving the answer ahead of the reasons—a device to save the time of busy readers. Then, for those who want to understand "why", it presents a streamlined textbook on the chemistry and arithmetic of combustion. The four articles in this section are "theory"—*practical* theory designed for dollar-saving application.

Next, moving from laboratory to actual boiler furnace, the four articles of "How to Burn Fuels" show what really happens when commercial fuels are burned on fuel beds and in suspension—also gives the practical slant on smoke, flyash and cinder.

Taken together, these two divisions cover half the problem: *how to use fuel right.* But that is not enough; the engineer dare not overlook the additional dollars to be saved by intelligent fuel selection. Millions of words have been written on this subject, so many, in fact, that most engineers would be licked before they started if they should attempt to review all the valuable literature of the subject. Here in 14 pages, including convenient charts, maps and tables, they will find a practical foundation for their fuel-buying operations.

How important is all this? The answer is found in America's bill for steam fuel. Eliminating all fuel supplied to ships, locomotives, domestic heating, coke making, etc—considering only that used to generate steam in the power boilers of central stations, industrials, institutions and large buildings—this bill (for Btu delivered to the boiler room) is around $800,000,000 per year. Of this fuel much less than half is scientifically purchased and burned; the larger portion is bought by hunch or custom, and burned with substantial preventable waste. Conservatively speaking, at least $80,000,000 of this total would be saved if all plants bought and burned as well as those who do the job best.

If power men, with better and more available information, go only a tenth of the way toward this goal, salvage as little as one per cent of their fuel bill, the national saving will be $8,000,000 yearly.

In a game where the stakes are of this order, or higher, the power engineer, who controls the spending of the $800,000,000, has ample incentive to study his cards and play them shrewdly.

CONTENTS

HOW TO FIGURE COMBUSTION

The Easiest Way 58
Chemical ABC's 61
How to Figure Volumes 62
Working by Analysis 66

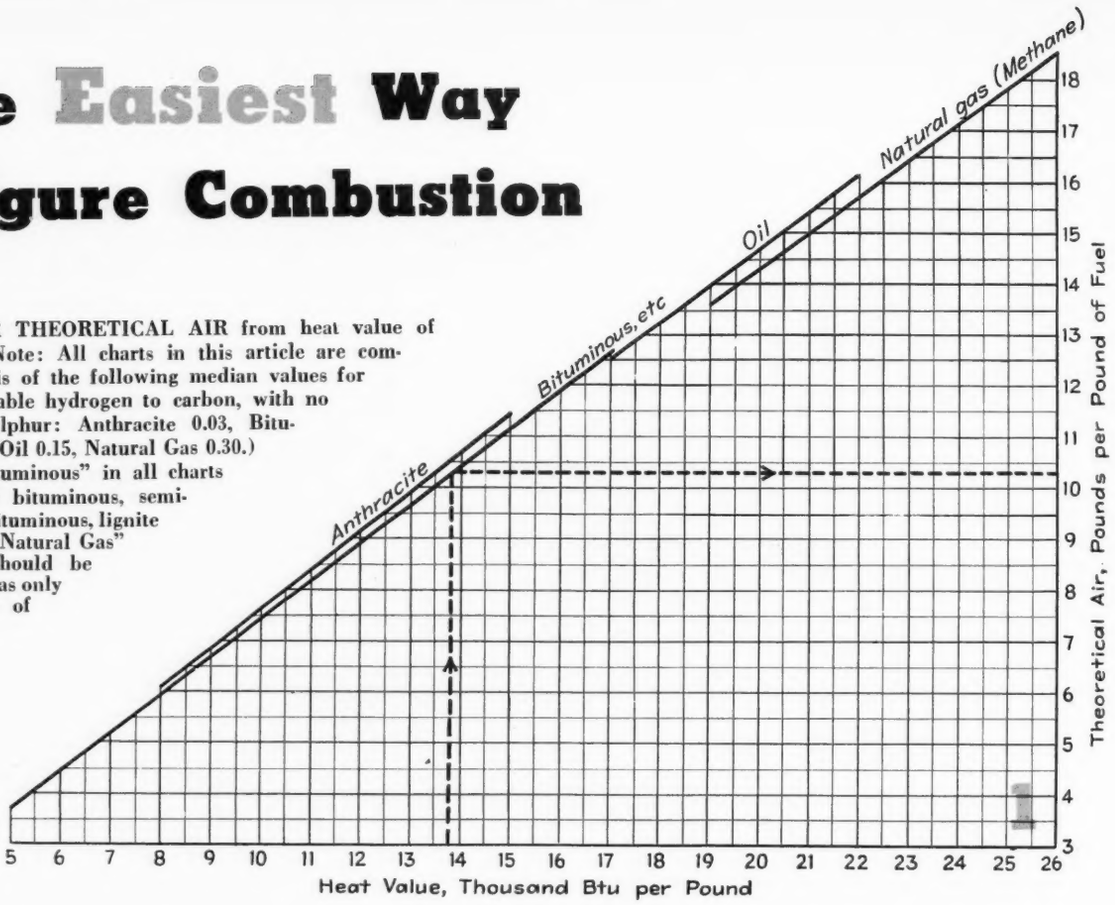
HOW TO BURN FUEL

Fuels in Action 78
Fuel-Bed Firing 80
Burner Firing 82
Smoke, Flyash and Cinder 84

HOW TO BUY FUEL

The Solid Fuels 68
Map of Coal-Producing Districts 72
Table of Typical Analyses 73
Table of Coal Shipments 74
Map of Market Areas 75
Liquid and Gaseous Fuels 76
Which Fuel for Your Plant? 85
Spending the Fuel Dollar 87

The Easiest Way to Figure Combustion


Natural gas (Methane)
Oil
Bituminous, etc
Anthracite
Theoretical Air, Pounds per Pound of Fuel
Heat Value, Thousand Btu per Pound
3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26

1—CHART FOR THEORETICAL AIR from heat value of coal as fired. (Note: All charts in this article are computed on the basis of the following median values for the ratio of available hydrogen to carbon, with no correction for sulphur: Anthracite 0.03, Bituminous 0.05, Fuel Oil 0.15, Natural Gas 0.30.) The line for "Bituminous" in all charts may be used for bituminous, semi-bituminous, sub-bituminous, lignite and wood. The "Natural Gas" lines, however, should be used for natural gas only consisting mainly of methane

Like cake, the "easiest" way to solve a problem is generally reserved for the last—a reward for the student who has first learned the hard way. Here we reverse the procedure by starting with the short cuts, which show how to get quick answers to the more important combustion problems—answers close enough for every-day records

THIS INTRODUCTORY article assumes that the reader: (1) is a busy man, (2) wants practical answers to combustion problems in a hurry, (3) knows the heat value of his fuel (and preferably, but not necessarily, the ash and moisture also), (4) has no complete fuel analysis, (5) is satisfied with a degree of accurary close enough to guide everyday operation.

It is also assumed that he has the equipment to measure flue-gas temperature and CO_2. (Determination of CO and O_2 also is helpful, but not absolutely essential). The method is best explained by working out an actual problem, using the following data:

Kind of Fuel....Bituminous coal
Heat value, as fired....13,800 Btu
Room temperature..... 80 F
Flue temperature..... 520 F
Flue-gas analysis:
% CO_2 ..... 10.2
% CO 0.6
% O_2 ..... 9.2
Boiler efficiency (by test), % 74.4

In the following steps *all weights* (except where otherwise noted) are *per pound of coal "as fired"*, not per pound of "dry" coal. (See "As Fired vs Dry", page 60).

Theoretical Air (From Fig. 1) = 10.3 lb.

Water in flue gas comes from three sources: (1) water originally in coal, (2) water produced by burning of available hydrogen in coal, and (3) moisture in air supplied. Of these we shall actually figure only (2), which is generally five or ten times as much as (1). We shall not attempt to figure (3), which is unimportant from the angle of every-day operation.

Water Produced by Burning Available Hydrogen (From Fig. 2) = 0.35 lb.

Since original moisture in coal is not known in this case, we shall assume it to be 0.05 lb. Any error in this assumption will be of little practical importance in figuring the moisture heat loss (except with lignite, wood and very wet coals). Then:

Total Water from Burning of Coal = 0.35 lb + 0.05 lb = 0.40 lb.

Gas Analysis & Excess Air

Add CO_2 and $\frac{1}{2}$ CO to get 10.2+0.3= 10.5%. Applying this value to Fig. 3B, we arrive at 75% excess air. Fig. 3B shows that, for this CO_2 and CO, the O_2 should be about 9.2%. This last checks with the actual O_2 found by analysis, and indicates that the analysis is consistent for bituminous coal. If the CO_2 only is known, and the CO is believed to be zero or negligible, enter chart 3B with the CO_2 value to get the excess-air percentage.

Actual Air = 175% of theoretical = 1.75 x 10.3 = 18.0 lb.

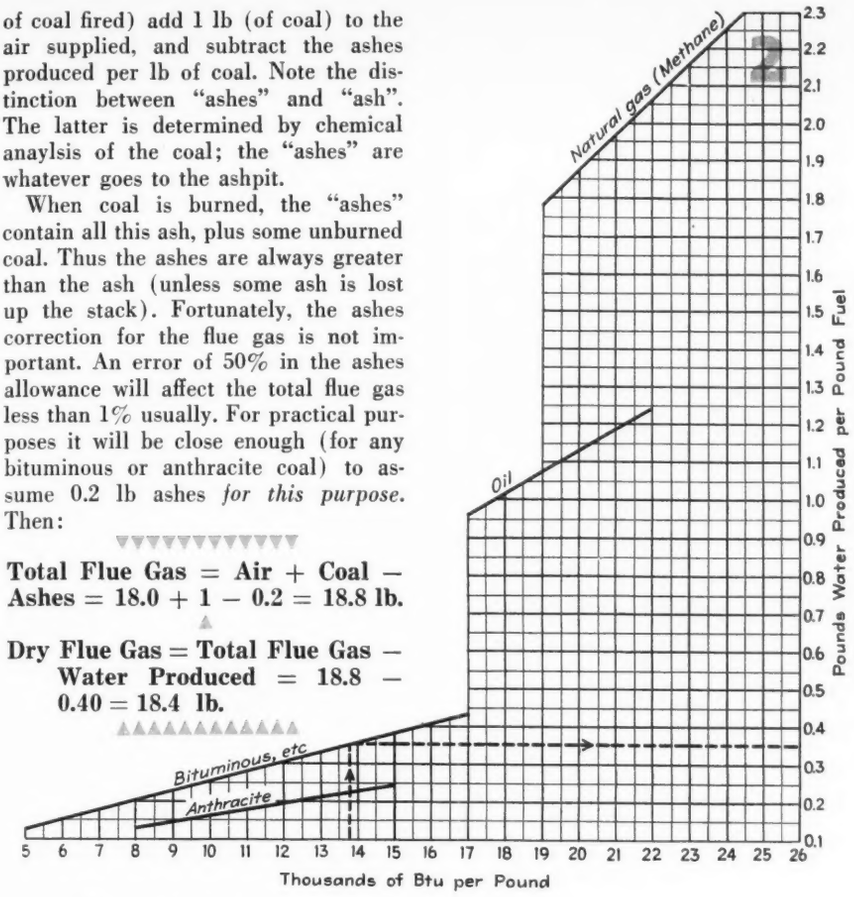
Practically speaking, everything fed to the furnace ultimately goes up the stack or into the ashpit. Therefore, to get the total weight of flue gas (per lb

of coal fired) add 1 lb (of coal) to the air supplied, and subtract the ashes produced per lb of coal. Note the distinction between "ashes" and "ash". The latter is determined by chemical anaylsis of the coal; the "ashes" are whatever goes to the ashpit.

When coal is burned, the "ashes" contain all this ash, plus some unburned coal. Thus the ashes are always greater than the ash (unless some ash is lost up the stack). Fortunately, the ashes correction for the flue gas is not important. An error of 50% in the ashes allowance will affect the total flue gas less than 1% usually. For practical purposes it will be close enough (for any bituminous or anthracite coal) to assume 0.2 lb ashes *for this purpose.* Then:

Total Flue Gas = Air + Coal − Ashes = 18.0 + 1 − 0.2 = 18.8 lb.

Dry Flue Gas = Total Flue Gas − Water Produced = 18.8 − 0.40 = 18.4 lb.



2—CHART FOR MOISTURE PRODUCED by combustion (of available H_2 in fuel) from heat value of coal as fired

Largest loss in steam generation is in "heating up the sky" by the sensible (perceptible) heat in the dry flue gas. This loss is proportional to the amount of dry gas and to the degrees it is heated above room temperature.

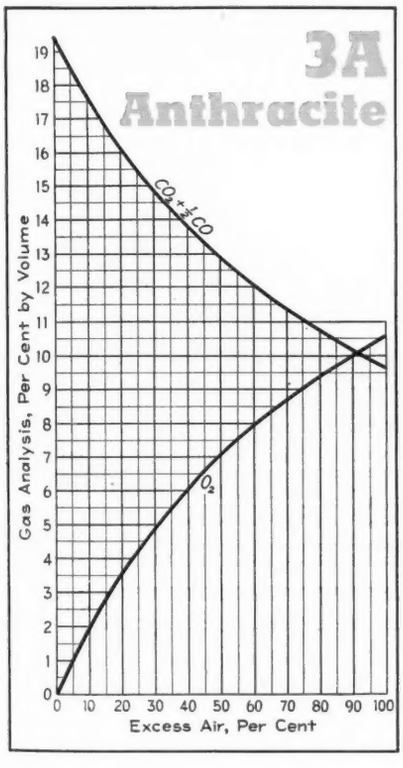
Sensible Heat Loss in Dry Gas = Weight Dry Gas × Temp Rise × Specific Heat = 18.4 × (520 − 80) × 0.25 = 2020 Btu

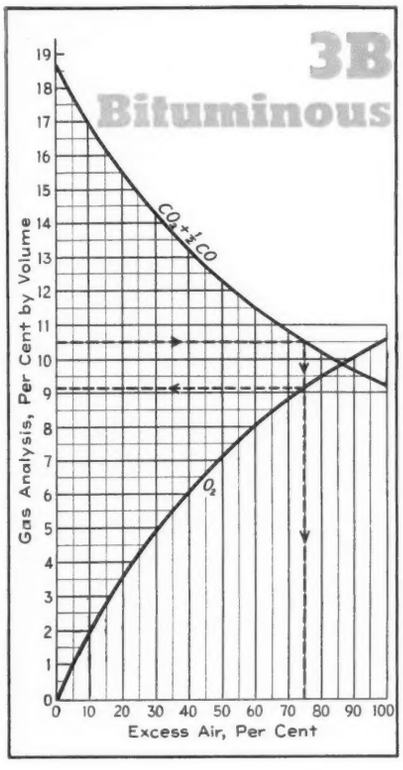
(This and subsequent Btu figures are rounded off to the nearest 10 Btu. The method doesn't warrant closer figuring.)

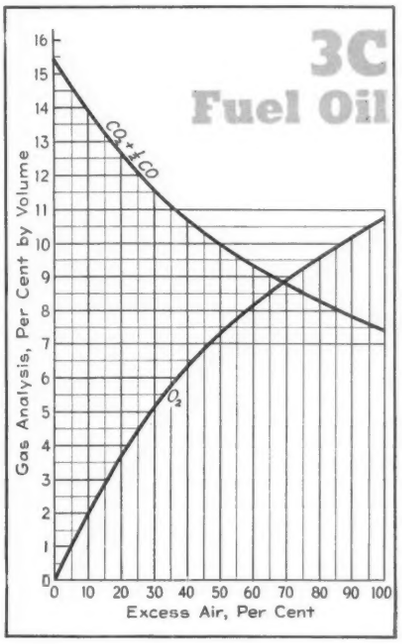
Moisture Loss

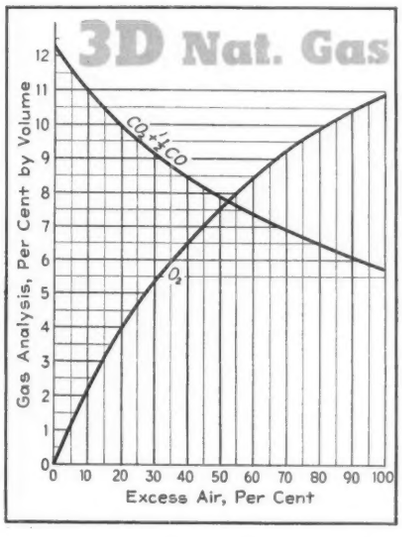
The water in the coal as fired and the water produced by burning available hydrogen in the coal must be heated to

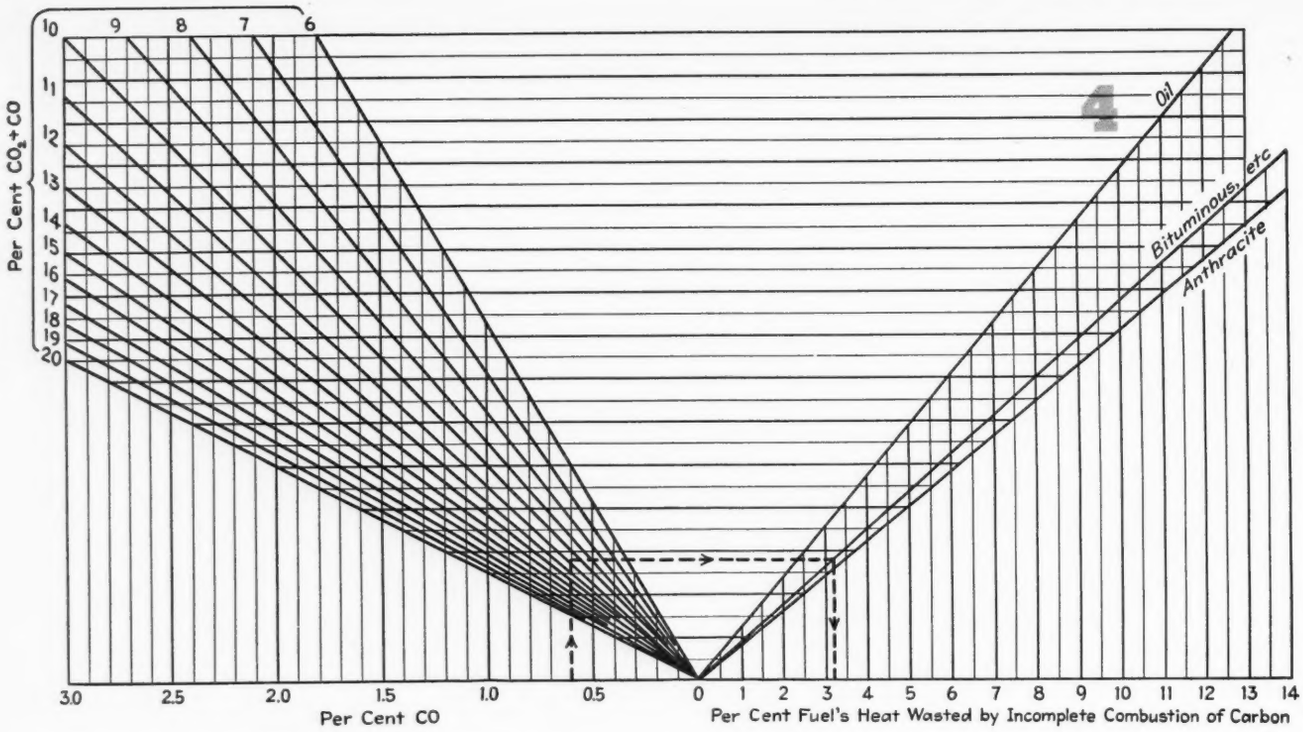
3—CHARTS FOR PERCENTAGE EXCESS AIR and for checking consistency of flue-gas analysis. Enter at left with $CO_2+\frac{1}{2}$ CO (or with CO_2 alone, if CO is not known, and is probably negligible). Move right to curve marked "$CO_2+\frac{1}{2}$ CO", then down to scale reading percentage excess air. To check consistency of flue-gas analysis, move left from the intersection of vertical line and curve marked "O_2". The corresponding reading of O_2 on left scale should be nearly the same as the O_2 shown by analysis. Otherwise suspect error in analysis










Per Cent CO_2+CO
10 9 8 7 6
11 12 13 14 15 16 17 18 19 20
4
Oil
Bituminous, etc
Anthracite
3.0 2.5 2.0 1.5 1.0 0.5 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
Per Cent CO
Per Cent Fuel's Heat Wasted by Incomplete Combustion of Carbon

4—CHART FOR INCOMPLETE COMBUSTION LOSS. Enter at lower left with percent CO. Move vertically to sum "CO_2+CO", right to kind of fuel, and down to scale showing loss expressed as a percentage of total heat of fuel as fired

212 F, then evaporated, then superheated to the flue-gas temperature. The following formula gives the heat required to put 1 lb of water through these steps, starting with room temperature of 80 F. No appreciable error is introduced if the same formula is used for room temperatures from 60 to 100 F.

Moisture Heat Loss per Lb Water = 1000 + ½ Flue Temp = 1000 + 260 = 1260 Btu

Moisture Heat Loss per Lb Coal = Loss per Lb Water × Lb Water per Lb Coal = 1260 × 0.4 = 500 Btu

The loss due to incomplete combustion of the carbon to CO (rather than to CO_2) is obtained directly as a percentage of the total heat in the fuel: Enter Fig. 4 at lower left with percent CO (0.6). Move straight up to slanting line marked sum of CO_2 and CO (10.8). Move right to line marked "Bituminous". Move down to read percent loss on lower right-hand scale.

Incomplete Combustion Loss (Fig. 4) = 3.2%

Heat Balance

To get a clear picture of what is happening to the coal dollar, the foregoing answers should be set up, along with the boiler efficiency (as determined by direct test), in the form of a heat balance. First make out form as shown below and fill in the known items, thus:

	Btu	%
Dry-gas loss (sensible heat) ...	2020	**14.6**
Moisture loss	500	**3.6**
Incomplete combustion loss	**440**	3.2
Unaccounted losses.	**570**	**4.2**
Total losses	**3530**	**25.6**
Useful heat	**10,270**	74.4
Heat in coal as fired	13,800	100.0

To make the operations clear, we have entered in red the items originally known, and in black those easily derived. Following shows how black items are filled in:

Dry-gas loss, % = 2020 ÷ 13,800 = 14.6%

Moisture loss, % = 500 ÷ 13,800 = 3.6%

Incomplete combustion loss, Btu = 13,800 × 0.032 = 440 Btu

Total losses, % = 100 − 74.4 = 25.6%

Useful heat, Btu = 0.744 × 13,800 = 10,270 Btu

Total losses, Btu = 13,800 − 10,270 = 3530 Btu

Unaccounted Btu = 3530 − (2020 + 500 + 440) = 3530 − 2960 = 570 Btu

Unaccounted, % = 25.6 − (14.6 + 3.6 + 3.2) = 25.6 − 21.4 = 4.2%

The unaccounted losses of 4.2% include in this case chiefly the following: (1) the undetermined loss of carbon to the ashpit, (2) the undetermined radiation loss from furnace and boiler, (3) the cumulative error (plus or minus) of all data and computations.

Carbon Loss

Carbon loss to the ashpit is usually figured from an analysis of the coal and of the ashes. This article assumes that no analysis of either is available. If the percent ash in the coal as fired is known, the carbon loss can be figured directly from measurements of coal fired and ashes produced. To illustrate, let's assume the following data:

Ash in coal as fired (by analysis) is 7.4%. Ashes produced per lb of coal fired is 0.096. Then the ashes from each lb of coal fired must contain 0.096 − 0.074 = 0.022 lb of combustible material. Since this will be pretty well "cooked", figure it as pure carbon, 14,600 Btu per lb. Then, carbon loss = 0.022 × 14,600 = 320 Btu.

This method cannot be used where substantial amounts of carbon are lost up the stack (in certain cases with pulverized fuel and with stokers on heavy forced draft).

Where carbon loss is figured it should, of course, be inserted in the heat balance, reducing the "unaccounted" losses by that amount.

"As Fired" vs "Dry"

The operator is interested in the heat value and analysis of his coal as it is fired. The "as fired" analysis and heat

value will vary with the moisture. The moisture, in turn, is constantly changing during mining, shipping and storing. Thus chemists and coal men sometimes prefer to quote the analysis of dry coal and give the moisture separately.

However, all of the foregoing computations, and all the charts in this section, are based on coal "as fired". If the coal data in hand is on the dry basis, it must first be converted to the "as fired" basis. This requires knowing the percentage of water in the coal as fired. The analyses on page 73 will give some basis for such an estimate.

To illustrate the method of converting, let's assume that the coal on the "dry" basis has 12.4% of ash and 12,700 Btu per lb. If the moisture in the coal "as fired" is 4.5%, the conversion constant will be 1.00 — 0.045 = 0.955. Multiply the dry-basis figure by 0.955 to get the "as fired" figures. Working the other way, from "as fired" to "dry" basis, divide by the same constant.

These shortcuts are designed for the engineer who wants his answer and wants it quick and whose technical resources are limited. The combustion technicians of the large power plants, and other who make elaborate boiler tests and studies, have all the paraphernalia for a complete analysis of combustion conditions based on chemical mathematics. We can't be of much help to them.

Some of the men in smaller plants, after mastering the short cuts shown, will want to learn the elements of combustion chemistry and how to figure combustion problems from the complete analysis, using orthodox chemical methods throughout. Such an understanding will be particularly helpful when burning certain types of gaseous and waste fuels where empirical methods and rule of thumb are apt to fall down.

The pages immediately following are designed to make these matters clear.

In presenting these combustion short cuts we owe an explanation to the experts who will be down our necks for some of the assumptions made. Here are some possible questions and our answers:

Q—From a study of your charts it is evident that you assume both theoretical air and moisture produced by the available hydrogen in the fuel are directly proportional to the heat value of the coal. This might be permissible if you used a special constant for each grade of fuel. In fact, however, you use one constant for anthracite, one for fuel oil, one for natural gas and just one to cover semi-bituminous, bituminous, sub-bituminous and lignite and wood.

A—True. Nevertheless the charts and formulas will give values for heat losses within 2% of the fuel's heat value (generally closer) for practically any fuel within the given classifications.

Q—Why not work each case directly from the analysis of the coal?

A—The majority of small and medium sized plants have no facilities or funds for getting either a reliable sample or a reliable analysis of the coal. A "perfect" method is no good if you can't use it.

The CHEMICAL ABC's

Groundwork facts for the man whose chemistry is rusty, plus reference data for everybody

OF ALL THE CHEMICAL ELEMENTS, only the five listed in Table I enter commercial combustion problems. Of these five, the first three are combustibles, the first two are solid combustibles. Oxygen is not combustible, but will support the combustion of the first three. Nitrogen is inert—neither combustible, nor a supporter of combustion.

TABLE I—ELEMENTS ENTERING COMBUSTION PROBLEMS

Name	*Symbol*	*Atomic weight*	*Molecule*	*Molecular weight*	*Common state*
Carbon.....	*C*	12	..	..	Solid
Sulphur.....	*S*	32	..	..	Solid
Hydrogen.....	*H*	1	H_2	2	Gas
Oxygen.....	*O*	16	O_2	32	Gas
Nitrogen.....	*N*	14	N_2	28	Gas

Atomic Weights

Since the hydrogen atom is the lightest, its weight is called "one" so that it can be a weight unit for the others. Since a carbon atom weighs 12 times as much as a hydrogen atom, its atomic weight must be 12. Where an *element* is a gas, its molecule contains two atoms (note the symbols H_2, O_2 and N_2 in Table I), so the molecular weight must be double the atomic weight.

In the case of the elements that are solids (here, carbon and sulphur) the number of atoms in a molecule is unknown, so we simply write the atomic formulas: *C* and *S*.

Chemical Compounds

All the compounds of combustion are combinations of some two of these five elements. Those of primary concern in the burning of coal are shown in Table II.

The formula for sulphur dioxide, SO_2, shows that its molecule contains one atom of sulphur (weighing 32) and two atoms of oxygen (each weighing 16). These add up to the molecular weight of 64.

These four are the only possible true products of combustion, although they may be mixed with many others (such as nitrogen, oxygen, unburned fuel gases, etc) as they leave the combustion. Hydrocarbons (compounds of carbon and hydrogen—some gaseous, some liquid, some solid) are found in commercial fuel oils and gases, and to some extent in coal and wood also. Examples are methane (CH_4), acetylene (C_2H_2), ethylene (C_2H_4), ethane (C_2H_6). More about these on page 62.

Combustion

Combustion may be defined as the rapid combination of oxygen with an element, compound or mixture, accompanied by the evolution of heat. Whatever combines with oxygen is the combustible. If the combustible is completely consumed, combustion is "*complete*." If combustion is complete with no excess of unused oxygen, combustion is "*perfect*." Note the difference.

Basic Combustion Equations

A simple example of combustion is the combining of hydrogen gas with oxygen gas to make water. The equation *might* be written:

$$H_2 + O = H_2O$$

but this is not good practice, because the elemental gases should always appear in these equations as complete molecules of two atoms each. This is taken care of here by doubling both sides to read:

	$2H_2$	+ O_2	=	$2H_2O$
Weights:	4	+ 32	=	36
	1 part	+ 8 parts	=	9 parts
	1 lb	+ 8 lb	=	9 lb

TABLE II—COMPOUNDS OF PRIMARY CONCERN IN BURNING COAL

Name	*Symbol*	*Molecular weight*	*Most common state*
Carbon dioxide	CO_2	44	gas — non combustible
Carbon monoxide	CO	28	gas — combustible
Sulphur dioxide	SO_2	64	gas — non combustible
Water	H_2O	18	liquid — non combustible

TABLE III—HEAT QUANTITIES FROM COMBUSTION

Reaction	*Heat*
1 lb carbon burning to CO_2	14,550 Btu
1 lb carbon burning to CO	4350 Btu
1 lb CO burning to CO_2	4350 Btu
1 lb hydrogen burning to H_2O	62,000 Btu
1 lb sulphur burning to SO_2	4000 Btu

One Btu is the heat required to raise the temperature of one pound of water 1 deg F. (Average from 32 F to 212 F).

Note that atoms balance on both sides of the equation. Note that weights also balance.

Formula for *complete* combustion of carbon to CO_2 is:

Weights:	C	+ O_2	= CO_2
	12	+ 32	= 44
	1 part	+ 2 2/3 parts	= 3 2/3 parts
	1 lb	+ 2.67 lb	= 3.67 lb

Formula for *incomplete* combustion of carbon to CO is:

Weights:	2C	+ O_2	= 2 CO
	24	+ 32	= 56
	1 part	+ 1 1/3 parts	= 2 1/3 parts
	1 lb	+ 1.33 lb	= 2.33

Formula for combustion of CO to CO_2

Weights:	2 CO	+ O_2	= 2 CO_2
	56	+ 32	= 88
	1 part	+ 4/7 parts	= 1 4/7 parts
	1 lb	+ 0.57 lb	= 1.57 lb

Formula for combustion of sulphur to SO_2 is:

Weights:	S	+ O_2	= SO_2
	32	+ 32	= 64
	1 part	+ 1 part	= 2 parts
	1 lb	+ 1 lb	+ 2 lb

Other Formulas

The foregoing formulas are those of interest, as far as weights are concerned, in the burning of coal and oil. For the sake of completeness, and for references when studying commercial gas fuels, the following are added for the more common hydrocarbon gases:

Methane

CH_4	+ 2 O_2	= CO_2	+ 2 H_2O
16	+ 64	= 44	+ 36
1 lb	+ 4 lb	= 2.75	+ 2.25 lb

Acetylene

$2C_2H_2$	+ 5 O_2	= 4 CO_2	+ 2H_2O
52	+ 160	= 176	+ 36
1 lb	+ 3.08 lb	= 3.39 lb	+ 0.69 lb

Ethylene

C_2H_4	+ 3 O_2	= 2 CO_2	+ 2 H_2O
28	+ 96	= 88	+ 36
1 lb	+ 3.42 lb	= 3.14 lb	+ 1.28 lb

Ethane

2 C_2H_6	+ 7 O_2	= 4 CO_2	+ 6 H_2O
60	+ 224	= 176	+ 108
1 lb	+ 3.73 lb	= 2,93 lb	+ 1.8 lb

How to Figure Volumes

Many combustibles and combustion products are gases, often most conveniently measured and figured by volumes. Here is a simple statement of the volumetric physics and chemistry of combustion, with data for solving problems

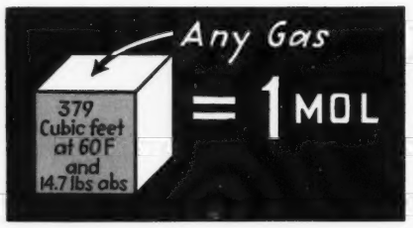


Fig. 1—Weight of 1 mol is molecular weight *in pounds*

ALL OF THE basic chemistry of the preceding article was in terms of weights. A knowledge of volume relations is almost equally important because all of the combustion products, and many combustibles, are gases.

Physics gives us three basic laws of gases, all important—the laws of Charles, Boyle and Avagadro.

Charles' Law

CHARLES' LAW: *If a given weight of gas is kept at constant pressure, its volume will be proportional to its absolute temperature.* Thus, if you double the absolute temperature you double the volume. Absolute temperature = deg F + 460.

Problem: What will happen to the volume of 400 cu ft of gas if the temperature is raised from 60 F to 600 F without change of pressure?

Solution: Original absolute temperature is 60 + 460 = 520. Final absolute temperature is 460 + 600 = 1060. Ratio is 1060 ÷ 520 = 2.04, so final volume = 2.04 × 400 = 816 cu ft.

Boyle's Law

BOYLE'S LAW: *If a given weight of gas is kept at constant temperature, its volume will be inversely proportional to the absolute pressure.* Thus, if you double the pressure, without changing the temperature, you cut the volume in half. Absolute pressure is gage pressure plus 14.7 lb per sq in. (at standard sea-level barometric pressure).

Problem: What will happen to 400 cu ft of gas at 10 lb g if the pressure is raised to 80 lb g without changing the temperature?

Solution: Original absolute pressure is 10 + 14.7 = 24.7 lb per sq in. Final absolute pressure is 80 + 14.7 = 94.7. Then, ratio is 94.7 ÷ 24.7 = 3.83, so final volume = 400 ÷ 3.83 = 153.2 cu ft.

Most practical men "sense" Charles'

law and Boyle's law in a general way. They know that gas expands if the temperature rises, contracts if you increase the pressure. Avagadro's law is almost as useful as Charles' and Boyle's, but less widely understood.

AVAGADRO'S LAW (STATEMENT 1): *At given pressure and temperature all gases have the same number of molecules per cubic foot.*

AVAGADRO'S LAW (STATEMENT 2): *At given pressure and temperature the weight of one cubic foot of any gas is directly proportional to its molecular weight.*

Statement 2 follows directly from Statement 1. Now if the volume is picked right the number expressing the actual weight in pounds will be exactly the same as the number expressing the molecular weight. For standard conditions (60 F and 14.7 lb absolute), this volume will be 379 cu ft.

The "Mol"

This *quantity* of any gas, whether you express it in pounds or as 379 cu ft at standard conditions, is called one "pound mol," or, for short, simply one "mol."

Thus a mol of hydrogen is 2 lb of hydrogen (since the molecular weight of H_2 is 2). Likewise a mol of oxygen (O_2) is 32 lb, and so on for all gases. (Note: The *weight* of a mol is not affected by changes of pressure and temperature, but the *volume* does change—thus at 32 F and 14.7 lb absolute, the volume of a mol is 359 cu ft.)

By simple algebra the laws of Charles, Boyle and Avagadro can be combined into a single formula relating pressure, volume and temperature for any gas. If you remember this formula and the molecular weights, you can figure gas volumes and weights entirely without tables. Here is the formula:

$PV = KT$, where

$K = 10.7 \div$ molecular weight

$P =$ absolute pressure, lb per sq in.

$V =$ volume of 1 lb of the given gas, cu ft

$T =$ absolute temperature

For convenience this can be written in the following three ways:

(1) Pressure $= K \times$ temperature $\div$ volume

(2) Volume $= K \times$ temperature $\div$ pressure

(3) Temperature $=$ pressure $\times$ volume $\div K$

(In all of the foregoing, remember that *temperature and pressure must be absolute.*)

Problem: Without referring to any tables, find the volume of 1 lb of nitrogen at atmospheric pressure and 60 F.

Solution:

Absolute pressure $= 0 + 14.7 =$ 14.7 lb abs

Absolute temperature $= 60 + 460 =$ 520 deg

For nitrogen, $K = 10.7 \div 28 =$ 0.382

Volume $= K \times$ temperature $\div$ pressure $= 0.382 \times 520 \div 14.7 =$ 13.5

Since this was figured for standard pressure and temperature, let's check the volume of one mol by multiplying by 28, thus: $28 \times 13.5 = 379$ cu ft (checks).

Here are two more convenient formulas:

At 60 F and 14.7 lb absolute,

Volume of 1 lb of gas $= 379 \div$ molecular weight

Weight of 1 cu ft of gas $=$ molecular weight $\div 379$

Fig. 2 shows all the more common combustion reactions in terms of volumes. Note that the formulas are the same as shown on page 60. Volume of each gaseous substance is directly proportional to the number of its molecules in the equation. Thus two *molecules* of CO combine with one *molecule* of O_2 to produce two molecules of CO_2. Also two *volumes* of CO combine with one *volume* of O_2 to make 2 *volumes* of CO_2. Also (since the mol is a unit of volume, 379 cu ft under standard conditions) two *mols* of CO combine with 1 *mol* of O_2 to make 2 *mols* of CO_2. Finally, any time we wish, we may turn the mols right back again into pounds, thus:

2×28 lb of CO + 32 lb $O_2 = 2 \times$ 44 lb CO_2

56 lb CO + 32 lb $O_2 =$ 88 lb CO_2

Clearly, the mol is extremely convenient when figuring combustion problems involving the analysis of flue gases or of fuel gases, as you can conveniently work in either volumes or weights and change back and forth quickly.

Note that the *weight* of a mol of CO_2

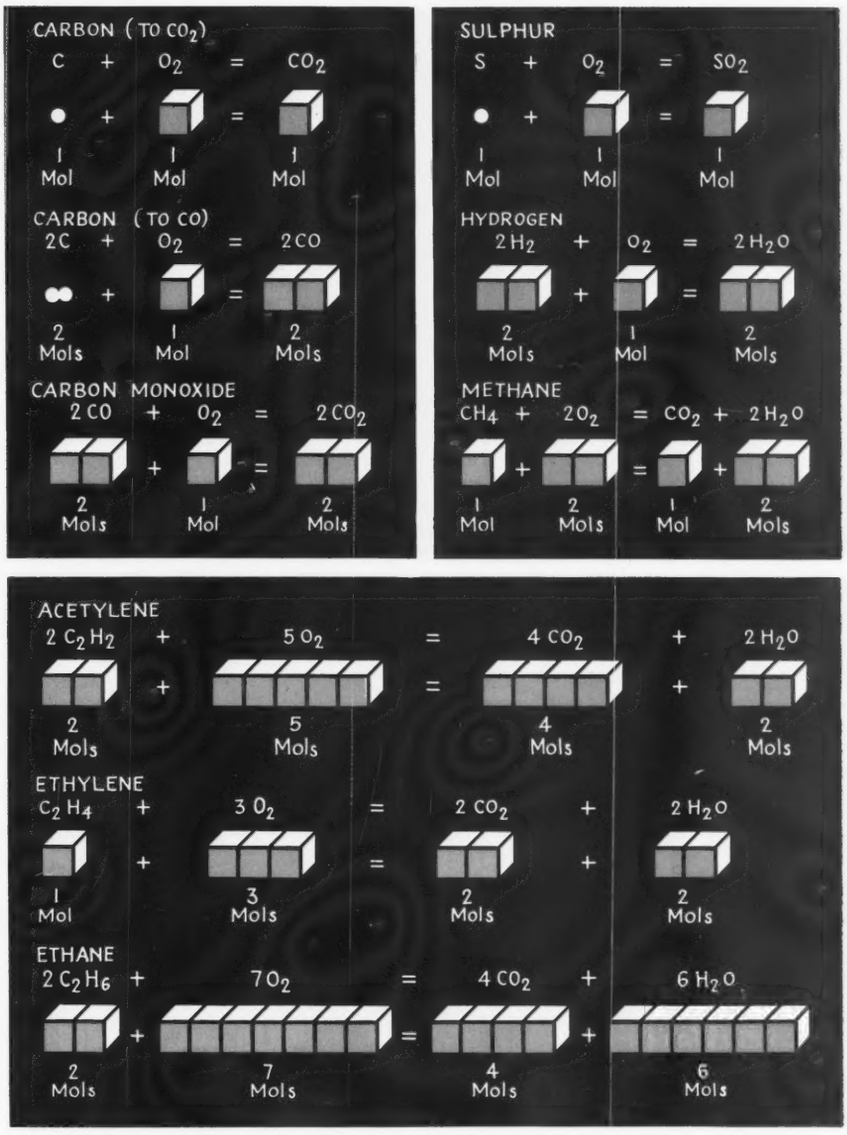

CARBON (TO CO_2)
C + O_2 = CO_2
1 Mol + 1 Mol = 1 Mol
CARBON (TO CO)
2C + O_2 = 2CO
2 Mols + 1 Mol = 2 Mols
CARBON MONOXIDE
2 CO + O_2 = 2 CO_2
2 Mols + 1 Mol = 2 Mols
SULPHUR
S + O_2 = SO_2
1 Mol + 1 Mol = 1 Mol
HYDROGEN
2 H_2 + O_2 = 2 H_2O
2 Mols + 1 Mol = 2 Mols
METHANE
CH_4 + 2 O_2 = CO_2 + 2 H_2O
1 Mol + 2 Mols = 1 Mol + 2 Mols
ACETYLENE
2 C_2H_2 + 5 O_2 = 4 CO_2 + 2 H_2O
2 Mols + 5 Mols = 4 Mols + 2 Mols
ETHYLENE
C_2H_4 + 3 O_2 = 2 CO_2 + 2 H_2O
1 Mol + 3 Mols = 2 Mols + 2 Mols
ETHANE
2 C_2H_6 + 7 O_2 = 4 CO_2 + 6 H_2O
2 Mols + 7 Mols = 4 Mols + 6 Mols

Fig. 2—The combustion equations in terms of volumes (mols). In every case the number of mols is the same as the coefficient of the molecule. Carbon and sulphur mols (white spots) follow the weight rule of all mols, but not the volume rule

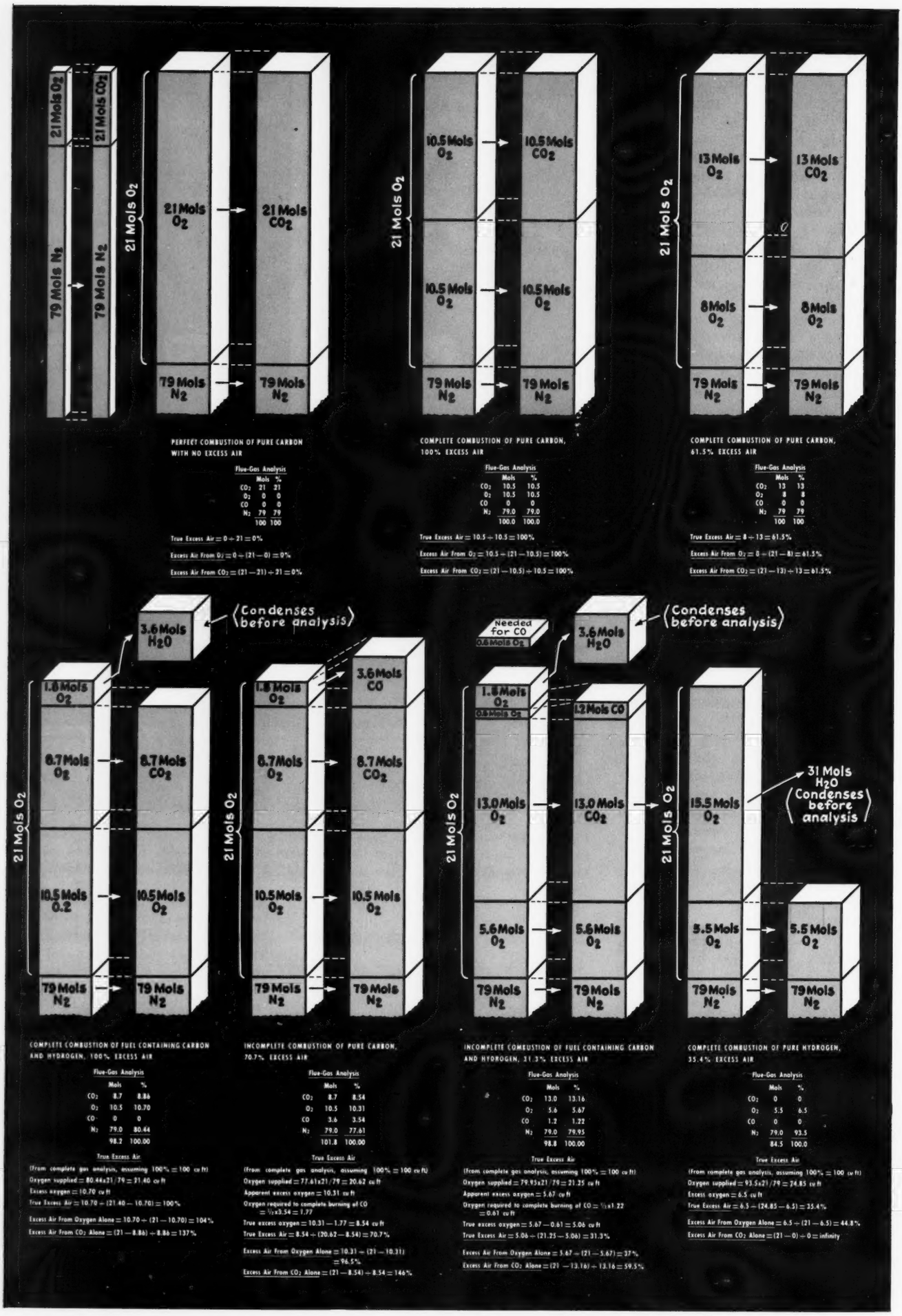

21 Mols O2
21 Mols CO2
79 Mols N2
21 Mols O2
21 Mols O2
21 Mols CO2
79 Mols N2
79 Mols N2
PERFECT COMBUSTION OF PURE CARBON WITH NO EXCESS AIR
Flue-Gas Analysis
Mols %
CO2 21 21
O2 0 0
CO 0 0
N2 79 79
100 100
True Excess Air = 0 ÷ 21 = 0%
Excess Air From O2 = 0 ÷ (21 − 0) = 0%
Excess Air From CO2 = (21 − 21) ÷ 21 = 0%
10.5 Mols O2
10.5 Mols CO2
10.5 Mols O2
10.5 Mols O2
79 Mols N2
79 Mols N2
COMPLETE COMBUSTION OF PURE CARBON, 100% EXCESS AIR
Flue-Gas Analysis
Mols %
CO2 10.5 10.5
O2 10.5 10.5
CO 0 0
N2 79.0 79.0
100.0 100.0
True Excess Air = 10.5 ÷ 10.5 = 100%
Excess Air From O2 = 10.5 ÷ (21 − 10.5) = 100%
Excess Air From CO2 = (21 − 10.5) ÷ 10.5 = 100%
13 Mols O2
13 Mols CO2
8 Mols O2
8 Mols O2
79 Mols N2
79 Mols N2
COMPLETE COMBUSTION OF PURE CARBON, 61.5% EXCESS AIR
Flue-Gas Analysis
Mols %
CO2 13 13
O2 8 8
CO 0 0
N2 79 79
100 100
True Excess Air = 8 ÷ 13 = 61.5%
Excess Air From O2 = 8 ÷ (21 − 8) = 61.5%
Excess Air From CO2 = (21 − 13) ÷ 13 = 61.5%
3.6 Mols H2O
⟨Condenses before analysis⟩
1.8 Mols O2
8.7 Mols O2
8.7 Mols CO2
10.5 Mols 0.2
10.5 Mols O2
79 Mols N2
79 Mols N2
COMPLETE COMBUSTION OF FUEL CONTAINING CARBON AND HYDROGEN, 100% EXCESS AIR
Flue-Gas Analysis
Mols %
CO2 8.7 8.86
O2 10.5 10.70
CO 0 0
N2 79.0 80.44
98.2 100.00
True Excess Air
(From complete gas analysis, assuming 100% = 100 cu ft)
Oxygen supplied = 80.44x21 / 79 = 21.40 cu ft
Excess oxygen = 10.70 cu ft
True Excess Air = 10.70 ÷ (21.40 − 10.70) = 100%
Excess Air From Oxygen Alone = 10.70 ÷ (21 − 10.70) = 104%
Excess Air From CO2 Alone = (21 − 8.86) ÷ 8.86 = 137%
3.6 Mols CO
8.7 Mols O2
8.7 Mols CO2
10.5 Mols O2
10.5 Mols O2
79 Mols N2
79 Mols N2
INCOMPLETE COMBUSTION OF PURE CARBON, 70.7% EXCESS AIR
Flue-Gas Analysis
Mols %
CO2 8.7 8.54
O2 10.5 10.31
CO 3.6 3.54
N2 79.0 77.61
101.8 100.00
True Excess Air
(From complete gas analysis, assuming 100% = 100 cu ft)
Oxygen supplied = 77.61x21 / 79 = 20.62 cu ft
Apparent excess oxygen = 10.31 cu ft
Oxygen required to complete burning of CO = ½x3.54 = 1.77
True excess oxygen = 10.31 − 1.77 = 8.54 cu ft
True Excess Air = 8.54 ÷ (20.62 − 8.54) = 70.7%
Excess Air From Oxygen Alone = 10.31 ÷ (21 − 10.31) = 96.5%
Excess Air From CO2 Alone = (21 − 8.54) ÷ 8.54 = 146%
Needed for CO
0.6 Mols O2
3.6 Mols H2O
⟨Condenses before analysis⟩
1.8 Mols O2
0.6 Mols O2
1.2 Mols CO
13.0 Mols O2
13.0 Mols CO2
5.6 Mols O2
5.6 Mols O2
79 Mols N2
79 Mols N2
INCOMPLETE COMBUSTION OF FUEL CONTAINING CARBON AND HYDROGEN, 31.3% EXCESS AIR
Flue-Gas Analysis
Mols %
CO2 13.0 13.16
O2 5.6 5.67
CO 1.2 1.22
N2 79.0 79.95
98.8 100.00
True Excess Air
(From complete gas analysis, assuming 100% = 100 cu ft)
Oxygen supplied = 79.95x21 / 79 = 21.25 cu ft
Apparent excess oxygen = 5.67 cu ft
Oxygen required to complete burning of CO = ½x1.22 = 0.61 cu ft
True excess oxygen = 5.67 − 0.61 = 5.06 cu ft
True Excess Air = 5.06 ÷ (21.25 − 5.06) = 31.3%
Excess Air From Oxygen Alone = 5.67 ÷ (21 − 5.67) = 37%
Excess Air From CO2 Alone = (21 − 13.16) ÷ 13.16 = 59.5%
15.5 Mols O2
31 Mols H2O ⟨Condenses before analysis⟩
5.5 Mols O2
5.5 Mols O2
79 Mols N2
79 Mols N2
COMPLETE COMBUSTION OF PURE HYDROGEN, 35.4% EXCESS AIR
Flue-Gas Analysis
Mols %
CO2 0 0
O2 5.5 6.5
CO 0 0
N2 79.0 93.5
84.5 100.0
True Excess Air
(From complete gas analysis, assuming 100% = 100 cu ft)
Oxygen supplied = 93.5x21 / 79 = 24.85 cu ft
Excess oxygen = 6.5 cu ft
True Excess Air = 6.5 ÷ (24.85 − 6.5) = 35.4%
Excess Air From Oxygen Alone = 6.5 ÷ (21 − 6.5) = 44.8%
Excess Air From CO2 Alone = (21 − 0) ÷ 0 = infinity

Fig. 3—This is what happens to volumes when air "burns". For the top row, where carbon is the only combustible in the fuel, where the fuel contains no nitrogen and where no CO is produced by combustion, any of the following formulas will give exact percentage of excess air (O_2 and CO_2 represent percentages by volume in the flue gas): *Formula 1:* % Excess Air = 100 x O_2 — (21 — O_2). *Formula 2:* % Excess Air = 100 x (21 — CO_2) x 100. These formulas are in error whenever the fuel contains available hydrogen. See comparison with exact method shown in the bottom row

is always 44 lb, regardless of pressure or temperature. Its *volume* is 379 cu ft at 14.7 lb abs and 60 F, also 359 cu ft at 14.7 lb abs and 32 F.

How about mols of the two solids encountered in combustion — carbon and sulphur? A mol of carbon is exactly 12 lb, and a mol of sulphur exactly 32 lb. Obviously, however, a mol of carbon at standard pressure is not 379 cu ft because it is not a gas. In the case of carbon and sulphur, therefore, consider the *weight* of the mol, but *not the volume* (which is of no concern anyway). To make this clearer, the mols of carbon and sulphur in Fig. 2 are represented by white spots rather than by cubes.

Another joker is H_2O, water. Water vapor is a gas, an imperfect gas that follows the gas volume formula roughly at high temperatures. When flue gas is analyzed the H_2O condenses to a liquid so that none of its volume shows up in the analysis.

"Burning" Air

In combustion we say that the fuel "burns" and the oxygen "supports combustion." It is just as logical, and sometimes more convenient, to say that the oxygen burns and that the uniting substance (hydrogen, carbon, etc) supports its combustion. This viewpoint is particularly helpful when studying the meaning of flue-gas analysis.

Fig. 3 shows seven examples of ways in which air can "burn" to flue gas, both air and flue gas being pictured in terms of volumes (mols). The air in every case has 79 parts by volume of nitrogen and 21 parts by volume of oxygen. Call it 79 mols of nitrogen and 21 mols of oxygen.

In every case the 79 mols go through to the flue gas unchanged. In No. 1 carbon is perfectly burned without excess air. The 21 mols of oxygen produce 21 mols of CO_2, and we get the analysis shown: 21% CO_2, no O_2, no CO and 79% N_2. Here the volume of flue gas (both reduced to 60 F and 14.7 lb abs) is the same as the volume of air, so the mols in the flue gas add up to 100. In this case the mols of each constituent are the same as the percentages of the flue-gas analysis.

In No. 2, with the same pure carbon fuel, and also with complete combustion, we split the 21 mols of oxygen into two equal portions, 10.5 mols burning to CO and 10.5 mols going unburned to the flue gas. Obviously the excess air is 100%. In this case the excess air can be figured without error from the CO_2 and O_2 in the flue gas or from the CO_2 alone or the O_2 alone, as shown at the bottom.

In No. 3 pure carbon is burned with less excess air. Here 13.0 mols of oxygen burn to 13.0 mols of CO_2 and 8 mols of oxygen are unburned excess. Here the exact percentage of excess air is unused oxygen ÷ used oxygen = 8 ÷ 13 = 61.5%. Here, also, the percentage of excess air can be figured exactly from either the CO_2 in the flue gas or the O_2 in the flue gas as shown at the bottom.

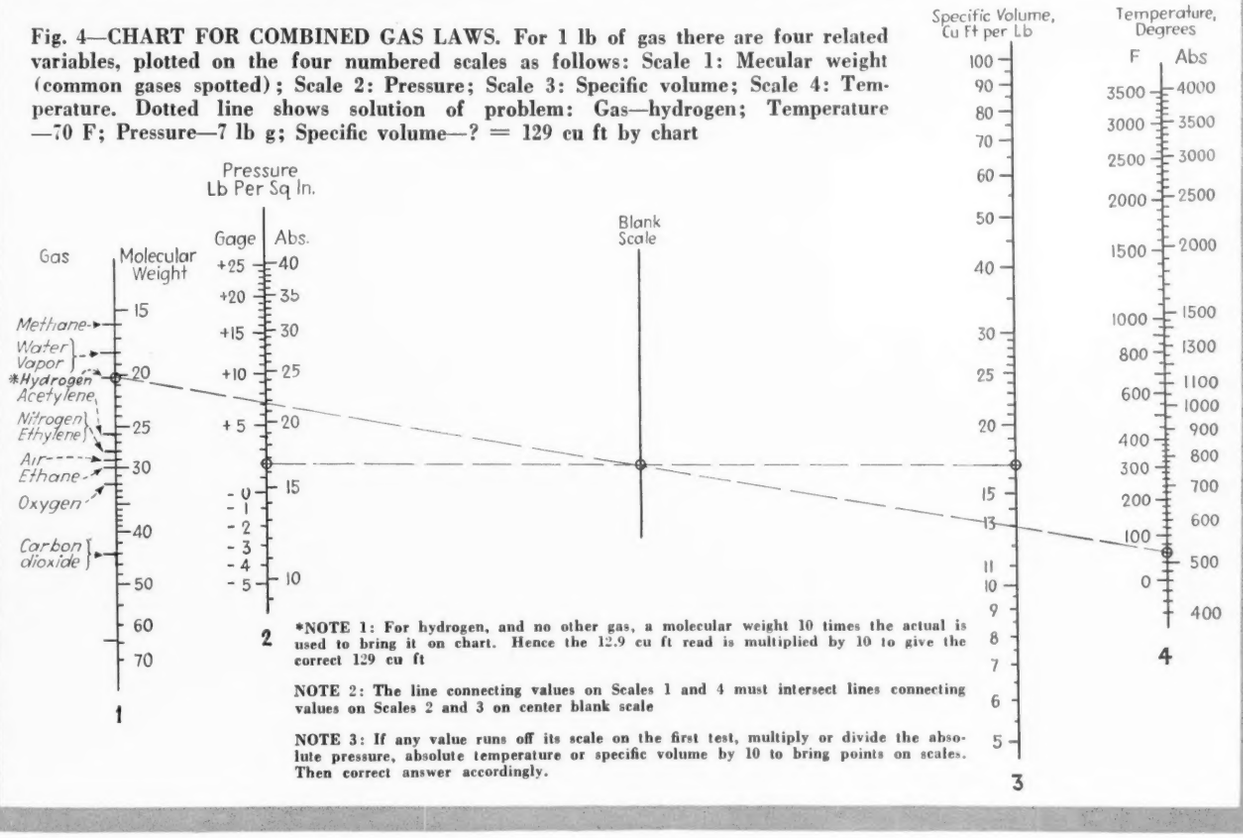
It must not be assumed, however, that the percentage of excess air can be figured exactly from CO_2 or O_2 in flue gas alone when burning commercial fuels. If the fuel contains any available hydrogen, or if the flue gas contains any CO, an error is introduced.

No. 4 illustrates the hydrogen error, No. 5 the carbon monoxide error, No. 6 the combination of the two errors, and No. 7 illustrates the extreme case of pure-hydrogen fuel where no CO_2 is produced, making the CO_2 analysis entirely useless.

In each of these cases the exact percentage of excess air can be figured from the complete gas analysis, as shown. In each a fair approximation of excess air can be figured from the oxygen in the flue gas and a rougher approximation (except for No. 7) from the CO_2. Note that the CO_2 method shows very serious errors for high-hydrogen fuels.

In every case the oxygen burning with hydrogen produces double its volume of water vapor, but this condenses so that it does not show up in the flue-gas analysis. Oxygen burning to carbon monoxide also doubles in volume, but does not condense.

Fig. 4—CHART FOR COMBINED GAS LAWS. For 1 lb of gas there are four related variables, plotted on the four numbered scales as follows: Scale 1: Mecular weight (common gases spotted); Scale 2: Pressure; Scale 3: Specific volume; Scale 4: Temperature. Dotted line shows solution of problem: Gas—hydrogen; Temperature —70 F; Pressure—7 lb g; Specific volume—? = 129 cu ft by chart


Pressure
Lb Per Sq In.
Gage
Abs.
Gas
Molecular Weight
Methane
Water Vapor
*Hydrogen
Acetylene
Nitrogen
Ethylene
Air
Ethane
Oxygen
Carbon dioxide
Blank Scale
Specific Volume, Cu Ft per Lb
Temperature, Degrees
F
Abs
1
2
3
4
*NOTE 1: For hydrogen, and no other gas, a molecular weight 10 times the actual is used to bring it on chart. Hence the 12.9 cu ft read is multiplied by 10 to give the correct 129 cu ft
NOTE 2: The line connecting values on Scales 1 and 4 must intersect lines connecting values on Scales 2 and 3 on center blank scale
NOTE 3: If any value runs off its scale on the first test, multiply or divide the absolute pressure, absolute temperature or specific volume by 10 to bring points on scales. Then correct answer accordingly.

Working from Analysis

How to solve combustion problems, using complete ultimate analysis of fuel and complete volumetric analysis of flue gas. Convenient reference tables give required basic data

THE EASIEST WAY to Figure Combustion, page 58, showed how to get approximate answers to combustion problems with little effort and without using the ultimate analysis of the coal. Such methods are close enough for most commercial purposes and are very important practically because, in many cases, no ultimate analysis of the fuel is available.

The methods shown on these two pages give closer results and are particularly valuable for such fuels as blast-furnace, coke-oven and producer gas, where more rule-of-thumb methods may go completely haywire.

Problem I—Coal

Given the coal and flue-gas analyses, the problem is to determine (per lb of coal) theoretical air, actual air, dry flue gas, moisture in flue gas—also the percent excess air and the percent loss from incomplete combustion. The method is to take a fixed amount of flue gas (100 mols) and find out the amount of carbon and nitrogen in it. Trace the carbon back to the coal. Trace the nitrogen back to the air. Then you know both the air and coal used to produce the same amount of flue gas.

With the following comments, the steps shown in the upper-left panel on the next page should be clear: **(1)** Analysis is by weight *as fired*. **(2)** Analysis is by volume. **(3)** Assume 100 mols of flue gas. Note that 1 mol of either CO_2 or CO contains 1 mol of carbon.

(4) Assume that all of the carbon in the coal goes to CO_2 and CO, none through the grate or up the stack. **(6)** All nitrogen in the air supplied goes into the flue gas. All nitrogen in the flue gas (except a negligible amount from the coal) comes from the air. **(7)** One mol of air weighs 29 lb.

(13) Every lb of carbon burning to CO wastes 10,160 Btu. **(15)** Column 1 comes from the coal analysis. Column 2 is from Table II, or directly from chemical equations. Column 3 is the product of Columns 1 and 2. The oxygen already in the coal is subtracted from that required for combustible elements to give that to be furnished by the air. Multiply this by 4.32 to get the weight of theoretical air.

This solution has been carried to the point where we know the theoretical air, percent excess air, actual air, dry flue gas, moisture. With these and room temperature, flue temperature and boiler efficiency, a heat balance can be figured as shown on page 60.

The method shown here for coal can be applied directly to oil and (with slight variations, since fuel-gas analysis is by volume) to gas fuels.

Problem II—Natural Gas

The problem is to determine the volumetric analysis of the flue gas if the given natural gas is burned with 40% excess air by volume. In this case computations are greatly simplified, since we can work throughout with volumes, expressed as mols.

(2) (right-hand panel on page 67) Column 2, directly from the analysis, gives the mols of each combustible constituent. To convert into other columns, multiply by the proper ratio either from the volumetric formulas on page 63, or from Table II. For example, 1 mol of C_2H_4 requires 3 mols of O_2 and produces 2 mols each of CO_2 and H_2O. Corresponding columns are then filled by multiplying 0.15 by 3, 2 and 2 respectively. Subtract the oxygen in the fuel from the total required to get the net to be furnished by air.

(3) Convert oxygen needed into nitrogen needed; then add 40% excess air and the nitrogen in fuel to get the total in the flue gas. **(4)** Figure free oxygen in flue gas as 40% of the theoretical requirements. **(5)** In tabulating mols in the flue gas for volumetric analysis, omit the H_2O because it condenses and does not appear in the analysis.

TABLE I—PROPERTIES OF COMBUSTION PRODUCTS AND COMMON COMBUSTIBLES

Substance	Formula	Molecular weight	At 14.7 lb. abs and 60 F		Nature		Heat value, B T U		
			Weight, lb per cu ft	Volume, cu ft per lb	Gas or solid	Combustible	Per pound	Per cu ft at 14.7 lb abs 60 F	Per mol
Carbon	C	12			S	C	14,540		174,500
Hydrogen	H_2	2.02	.0053	188	G	C	61,000	325	123,100
Sulphur	S	32			S	C	4,050		129,600
Carbon monoxide	CO	28	.0739	13.54	G	C	4,380	323	122,400
Methane	CH_4	16	.0423	23.69	G	C	24,000	1012	384,000
Acetylene	C_2H_2	26	.0686	14.58	G	C	21,500	1483	562,000
Ethylene	C_2H_4	28	.0739	13.54	G	C	22,200	1641	622,400
Ethane	C_2H_6	30	.0792	12.63	G	C	22,300	1762	668,300
Oxygen	O_2	32	.0844	11.84	G				
Nitrogen	N_2	28	.0739	13.52	G				
Air*		29	.0765	13.07	G				
Carbon dioxide	CO_2	44	.1161	8.61	G				
Water	H_2O	18	.0475	21.06	G				

* By volume, air is 79 parts nitrogen and 21 parts oxygen. The " molecular weight " of 29 is merely the weighted average of the molecular weight of the constituents.

PROBLEM I—COAL

Given complete analysis of coal and flue gas. To determine (per lb of coal) theoretical air, actual air, dry flue gas, moisture in flue gas — also per cent excess air and percent loss from incomplete combustion.

(1) Ult Analysis of Coal (as fired), % by Weight

Ash	10.49
Sulphur	1.20
Hydrogen	6.47
Carbon	71.98
Nitrogen	1.16
Oxygen	8.70
	100.00%
Btu per lb,	13,800

(2) Flue-Gas Analysis, Per Cent by Volume

CO_2	10.2
CO	0.6
O_2	9.2
N_2	80.0
	100.00%

(3) Figuring Mols of Carbon and Nitrogen in Flue Gas

Flue Gas	%	Mols Gas	Mols C	Mols N_2
CO_2	10.2	10.2	10.2	....
CO	0.6	0.6	0.6	....
O_2	9.2	9.2	....	....
N_2	80.0	80.0	....	80.0
Total mo's	....	100.0	10.8	80.0

(4) Weight carbon burned = 10.8 × 12 = 129.6 lb
(5) Weight coal burned = 129.6 ÷ 0.7198 = 180.0 lb
(6) Mols air supplied = 80.0 ÷ 0.79 = 101.3
(7) Weight air supplied = 101.3 × 29 = 2938 lb
(8) Ratio air to coal = 2938 ÷ 180.0 = 16.32 lb air per lb coal
(9) Moisture produced per lb coal = 0.0647 × 9 = 0.58 lb
(10) Dry flue gas per lb coal = coal + air − ash − moisture = 1 + 16.32 − 0.1049 − 0.58 = 16.64 lb

CO Loss

(11) Fraction of carbon burning to CO = 0.6 ÷ (10.2 + 0.6) = 0.0555
(12) Weight of carbon burning to CO = 0.0555 × 0.7198 = 0.040
(13) Heat loss from CO = 0.040 × 10160 = 406 Btu
(14) Percent heat loss from CO = 100 × 406 ÷ 13,800 = 2.94%
(15) Theoretical Air per Pound Coal

	Lb of Combustible	Lb O_2 Required per lb Comb.	Lb O_2 Required
Carbon	0.7198	2.67	1.922
Hydrogen	0.0647	8.00	0.518
Sulphur	0.012	1.00	0.012
Total			2.452
Less oxygen in the coal			0.087
Net oxygen needed			2.365 lb × 4.32 = 10.22 lb air

(16) Excess air = 16.32 − 10.22 = 6.10 lb
(17) Per cent excess air = 6.10 ÷ 10.22 = 59.7%

PROBLEM II—NATURAL GAS

Given volumetric analysis of a natural gas. To determine the volumetric analysis of the flue gas if the fuel is burned with 40% excess air (by volume).

(1) Gas Analysis by Volume, %

CO	0.60
H_2	1.62
CH_4	94.30
C_2H_4	0.15
H_2S	0.25
O_2	0.40
CO_2	0.85
N_2	1.83
Total	100.00

(2) Oxygen, Combustion Products for 100 Mols of Fuel

Gas	Mols	Mols O_2 Needed	Mols Produced CO_2	Mols Produced H_2O	Mols Produced SO_2
CO	0.60	0.30	0.60	....	.....
H_2	1.62	0.81	.....	1.62	.....
CH_4	94.30	188.60	94.30	188.60	.....
C_2H_4	0.15	0.45	0.30	0.30	.....
H_2S	0.25	0.37	.....	0.25	0.25
CO_2	0.85	.....	0.85	.....	.....
Total	.....	190.53	96.05	190.77	0.25
Less O_2 in fuel	.....	0.40	.....	.....	.....
	.....	190.13	96.05	190.77	0.25

(3) Figuring nitrogen in flue gas

N_2 required for 190.13 mols O_2 = 190.13 × 3.76 = 714.9 mols
40% excess N_2 (by volume) = 0.4 × 714.9 = 286.0
N_2 in fuel = 1.8
N_2 in flue gas = 1002.7 mols

(4) Unburned O_2 in flue gas = 0.40 × 190.13 = 76.0 mols

(5) Volumetric Gas Analysis (H_2O Disappears)

Gas	Mols	% by Vol.
CO_2	96.1	8.2
O_2	76.0	6.5
SO_2	0.2	0.0
N_2	1002.7	85.3
Total	1175.0	100.0

TABLE II—CONSOLIDATED COMBUSTION DATA

Gives required combustion air and products for common combustibles burned with theoretical air requirements. Air and products are given in mols, cu ft and lb (see right-hand column) for 1 mol, 1 cu ft and 1 lb of fuel

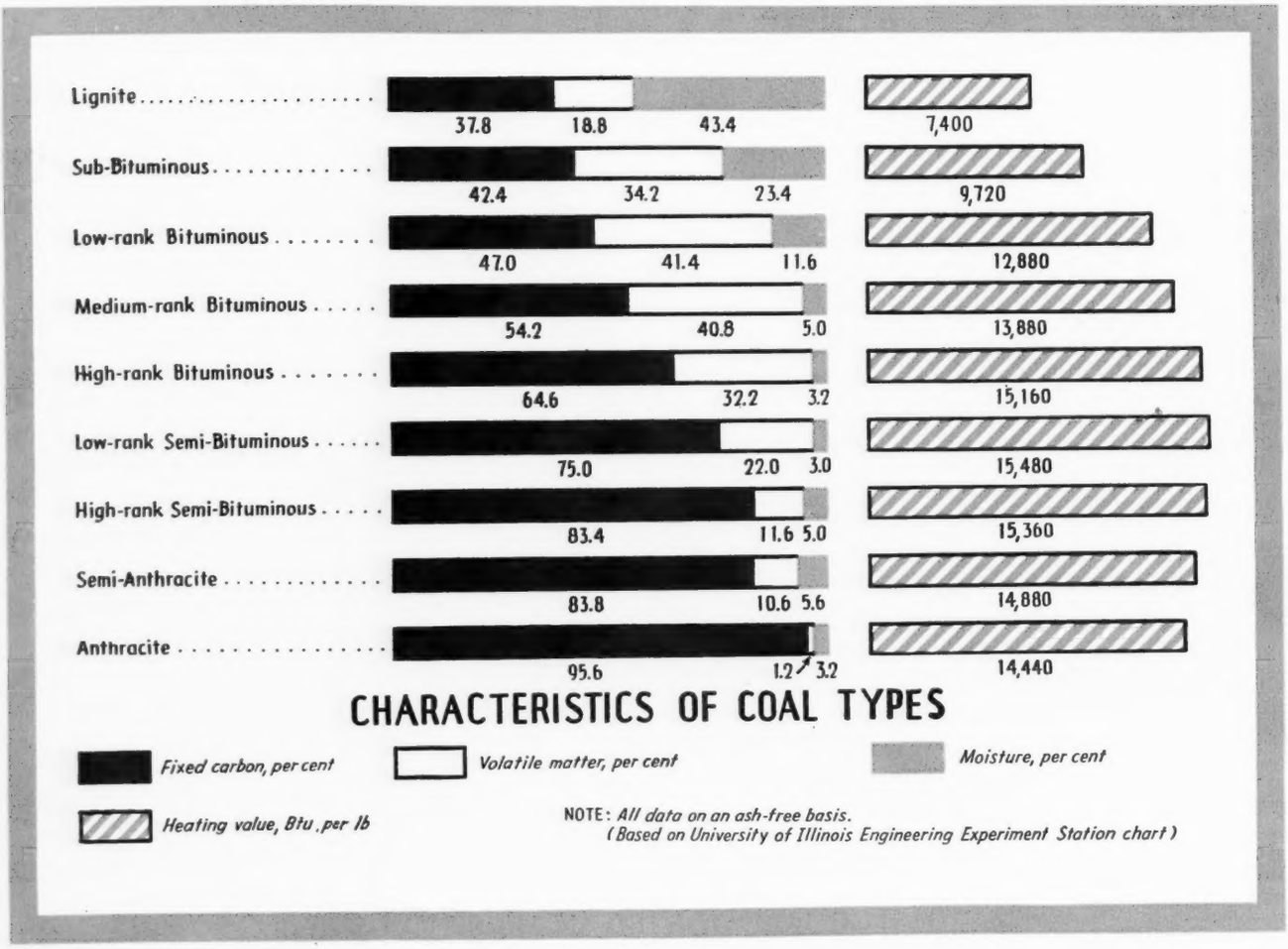
Air Required and Combustion Products

Fuel	For 1 mol of fuel: Air O_2	Air N_2	Other products (than N_2) CO_2	H_2O	SO_2	For 1 cu ft of fuel: Air O_2	Air N_2	Other products (than N_2) CO_2	HO_2	SO_2	For 1 pound of fuel: Air O_2	Air N_2	Other products (than N_2) CO_2	H_2O	SO_2	
	1.0	3.76	1.0								.0833	.313	.0833			Mols
C	379	1425	379								31.6	118.8	31.6			Cu. ft.
	32.0	105	44.0								2.67	8.78	3.67			Pounds
	0.5	1.88		1.0		.00132	.00496		.00264		.250	.940		0.5		Mols.
H_2**	189.5	712		379*		0.5	1.88		1.0*		94.8	356		189.5*		Cu. ft.
	16.0	52.6		18		.0422	.139		.0475		8.0	26.3		9.0		Pounds
	1.0	3.76			1.0						.0312	.1176			.0312	Mols.
S	379	1425			379						11.84	44.6			11.84	Cu. ft.
	32.0	105			64						1.0	3.29			2.0	Pounds
	0.5	1.88	1.0			.00132	.00496	.00264			.179	.0672	.0357			Mols.
CO	189.5	712	379			0.5	1.88	1.0			6.77	25.4	13.53			Cu. ft.
	16.0	52.6	44.0			.0422	.139	.116			.571	1.88	1.57			Pounds
	2.0	7.52	1.0	2.0		.00528	.0198	.00264	.00528		.125	.470	.0625	.125		Mols.
CH_4	758	2850	379	758*		2.0	7.52	1.0	2.0*		47.4	178	23.7	47.4*		Cu. ft.
	64.0	210	44.0	36.0		.169	.556	.116	.0950		4.0	13.17	2.75	2.25		Pounds
	2.5	9.40	2.0	1.0		.0066	.0248	.00528	.00264		.0962	.362	.0769	.0385		Mols.
C_2H_2	947	3560	758	379*		2.5	9.40	2.0	1.0*		36.4	137	29.15	14.58*		Cu. ft.
	80.0	263	88.0	18.0		.211	.694	.232	.0475		3.08	10.13	3.38	.692		Pounds
	3.0	11.29	2.0	2.0		.00792	.0298	.00528	.00528		.1071	.403	.0714	.0714		Mols.
C_2H_4	1137	4280	758	758*		3.0	11.29	2.0	2.0*		40.6	153	27.1	27.1*		Cu. ft.
	96.0	316	88.0	36.0		.253	.834	.232	.0950		3.43	11.29	3.14	1.286		Pounds
	3.5	13.17	2.0	3.0		.00923	.0347	.00528	.0079		.1167	.439	.0667	.10		Mols.
C_2H_6	1326	4990	758	1137*		3.5	13.17	2.0	3.0*		44.2	166.3	25.3	37.9*		Cu. ft.
	112.0	369	88.0	54.0		.296	.972	.232	.1425		3.73	12.29	2.93	1.8		Pounds

* The volumes shown for H_2O apply only where the combustion products are at such high temperature that all the H_2O is a gas.

** Varying assumptions for molecular weight introduce a slight inconsistency in the values of air and combustion products from the burning of hydrogen. True molecular weight of hydrogen is 2.02, but the approximate value of 2 is used in figuring the air and combustion products.

Facts About Solid Fuels



BECAUSE the physical form in which a fuel occurs determines the way it is prepared, shipped, handled, and fired, it is customary to classify fuels as *solid, liquid,* or *gaseous.* Solid fuels play a dominant role; wood led the field from antiquity to about 75 years ago; since then coal has been the world's major fuel.

Three-hundred-million years ago, in the swamp forests of the Carboniferous Age, was laid the foundation of our present coal supply. For fifty million years, giant trees and ferns grew and fell, to decay and form rich peat bogs. Floods buried the bogs under layers of sediment, only to subside and permit the cycle of growth and decay to begin again. As millions of years passed, pressure, heat, and time worked together to drive off some volatile matter, to harden the mass, and to turn it into the carbon-substance we call coal.

Different kinds of coal contain different amounts of carbon-substance, depending on the age of the deposit and the conditions under which it was formed. Next to the original peat, the "youngest" form of coal is *lignite,* high in moisture and low in fixed carbon. Older coals, higher in "rank," contain more fixed carbon. The chart gives a clear picture of the characteristics of typical coals and the map on page 72 shows where they occur. The present approved method of classifying coals by rank will be found in "ASTM Standards on Coal and Coke," published by American Society for Testing Materials, 260 Broad St, Philadelphia, Pa.

Analyses

To be able to express coal qualities in figures instead of words, various tests and methods of analysis have been devised. An *ultimate analysis* shows the exact chemical composition of a fuel, without paying any attention to the physical form in which the compounds appear. Such an analysis gives data needed for combustion calculations.

The *proximate analysis* gives a better picture of the behavior of coal in a furnace. It involves determining: (1) percentage of *moisture,* (2) percentage of *ash,* (3) percentage of *volatile matter,* and (4) percentage of *fixed carbon.* These percentages add up to 100. In addition, it is customary to determine: (1) the total amount of *sulphur,* expressed as a separate percentage, (2) the *ash-fusion temperature,* and (3) the *heating value,* in Btu.

There are five ways to report an analysis, although only the first three are likely to be met in power plants: (1) as received, (2) air-dried, (3) moisture-free, (4) moisture-and-ash-free, and (5) moisture-and-mineral-free. As the name implies, the *as-received* analysis reports the condition of the coal as delivered to the laboratory. This comes closest to giving the condition of the coal *as shipped* or *as fired,* the values desired in practical work. Loss or gain of moisture between time of sampling and of analysis depends on the kind of coal, size, weather conditions, and method of handling the sample.

For an *air-dried* analysis, the sample is crushed to about ¼ in. and exposed to air for 36 hours or longer (or kept 6 to 8 hours in a drier). To put the analysis on a *dry* or *moisture-free* basis it is only necessary to recalculate the percentages, eliminating the moisture. For certain theoretical comparisons, a

similar refiguring is used to arrive at percentages on a *moisture-and-ash-free* basis. Because there is more mineral matter in the original coal than appears as ash after burning, formulas have been worked out to figure this mineral content, making it possible to report on a *moisture-and-mineral-free* basis.

The following paragraphs indicate how coal characteristics are determined and how they affect the value of coal in power-plant operation. For exact details on equipment and procedures for testing coal, consult "ASTM Standards on Coal and Coke" and "Methods of Analyzing Coal and Coke," Bureau of Mines Technical Paper 8.

Moisture

All coal contains some natural moisture (ranging from 1 to 5% in Eastern coals and up to 40% in some Texas lignites). This *inherent* moisture lies in the pores of the coal and forms a true part of it, being retained when the coal is air-dried. *Surface* moisture depends on conditions in the mine, on length of time in transit, and on weather conditions. The capacity of a coal to retain surface moisture depends chiefly on size and uniformity.

A moisture determination involves heating a specially prepared sample in a preheated oven (at 220-230 F) for one hour. Loss of weight divided by original weight gives percent moisture.

Moisture must be transported, handled, and stored; its presence in large amounts increases the difficulty and cost of these operations. Looked at another way, moisture replaces an equal amount of combustible material and thus decreases the heat content per lb. In addition, some of the heat liberated in the furnace goes to evaporating the moisture in the fuel and superheating the vapor; this *moisture loss* can be figured from the chart on page 59.

Ash is the incombustible mineral matter left behind when coal burns completely. It differs from "ashes," as the power-plant operator knows them, because ashes taken from a furnace always contain some unburned coal. Laboratory determination of ash involves heating dried coal (after the moisture determination); until red hot; then heating continues at about 1300 F until a constant weight obtains. Weight of the remainder, divided by original sample weight, gives percent ash.

Like moisture, ash is an impurity which increases shipping and handling costs. It must be removed from the furnace and the plant, requiring additional equipment and expense in most cases. Recent research shows that amount and character of ash constitutes the biggest single factor in fuel-bed and furnace problems such as clinkering and slagging. An increase in ash content usually means an increase in carbon carried to the ashpit.

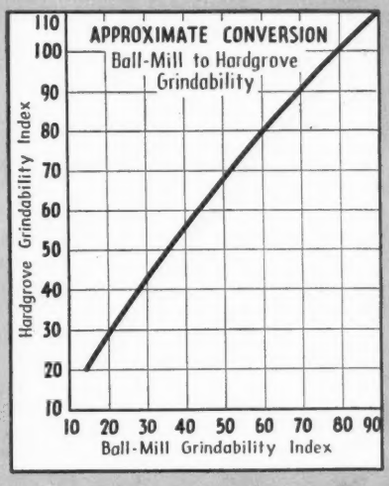
In a way not yet clearly known, coal holds combustible gases such as hydrogen, methane and other hydrocarbons, and incombustible gases such as carbon dioxide and nitrogen. Heat releases these gases, leaving behind a solid fuel, consisting, in the main, of carbon, but containing some hydrogen, oxygen, sulphur, and nitrogen not driven off with the gases. In the laboratory, *volatile matter* is measured by heating a sample at approximately 1750 F for exactly 7 minutes. The loss of weight, minus the moisture, divided by the original sample weight, gives the percentage of volatile matter. Subtracting the percentage of moisture, of ash, and of volatile matter from 100% yields a percentage called *fixed carbon.*

The percentage of volatile matter indicates the amount of gaseous fuel present and thus bears a direct relation to the mechanics of firing. It affects furnace volume and arrangement of furnace surfaces; for existing equipment, the amount of volatiles largely determines whether smoke forms or not.

Sulphur is an undesirable element in coal for power-plant use. It plays a part in clinkering and slagging, in corrosion of air heaters, economizers, breeching and stacks, and in spontaneous combustion of stored coal. It occurs mainly as iron sulphide (commonly known as pyrites), as organic sulphur, and in small amounts as sulphates. Laboratory determination of sulphur is too complex to describe here. Only total sulphur is measured, although it is known that the iron combined with the sulphur shares the blame for troubles laid to sulphur.

Ash-fusion temperature is measured by heating cones of ash in a gas furnace arranged to produce a reducing atmosphere. The temperature at which the cone fuses down to a round lump is called the *softening* or *ash-fusion temperature.* Other temperatures sometimes observed include that at which the tip of the cone starts to bend (*initial deformation temperature*) and that at which the cone spreads out in a flat layer (*fluid temperature*).

Ash-fusion temperature (and sometimes the spread between initial and softening or softening and fluid temperatures) serves as the best single indicator of clinkering and slagging tendencies under given fuel-bed and furnace conditions. Ash characteristics dictate whether a furnace shall have a dry bottom or a slag top.



HARDGROVE GRINDABILITY VALUES OF TYPICAL COALS

State	County	Seam	Grindability
Illinois	Christian	No. 6	57
	Fulton	No. 5	65
	Jackson	No. 6	75
	Saline	No. 5	58
	Vermilion	No. 6	63
Ohio	Belmont	Pittsburgh No. 8	57
	Jefferson	Pittsburgh No. 8	58
	Tuscarawas	Pittsburgh No. 6	57
Pennsylvania	Allegany	Pittsburgh	62
	Cambria	Lower Kittanning	104
	Fayette	Pittsburgh	61
	Indiana	Lower Kittanning	107
	Jefferson	Lower Freeport	96
	Somerset	Upper Kittanning	100
	Westmoreland	Pittsburgh	63
Tennessee	Anderson	Pee Wee	43
Virginia	Dickenson	Upper Banner	85
	Tazewell	Pocahontas No. 3	104
West Virginia	Boone	Winifrede	40
	Fayette	No. 2 Gas	58
	Fayette	Sewell	85
	Kanawha	Coalburg	43
	Logan	Chilton	59
	Marion	Pittsburgh	56
	McDowell	Pocahontas No. 3	103
	Monongalia	Pittsburgh	64
	Raleigh	Beckley	104

The heating value of coal is measured by burning a sample in a "bomb" calorimeter. Filling the bomb with oxygen under pressure insures a complete combustion. The value found by this test is the *higher heating value*, or *gross calorific value.* All fuels containing hydrogen have another heating value called the *lower* or *net calorific value.* The difference arises because hydrogen burns to form water vapor; if the vapor condenses and gives up its latent heat and superheat a higher heat output is registered than if the water vapor doesn't condense and the latent heat of vaporization and superheat is lost. The higher or gross value finds universal application in boiler-plant calculations.

The consumer really buys energy units when he buys fuel, and so the heating value, as a direct measure of the energy content, plays a basic part in judging fuel values. In some cases, the heating value of the fuel also affects the maximum capacity of the plant.

Wide use of pulverized-fuel firing brought a need for tests to show the

relative ease or difficulty of grinding different kinds of coal. The ASTM tentatively approves two methods, the *ball-mill* and the *Hardgrove machine.* In the first, the relative amounts of energy needed to pulverize different coals are measured by placing a sample in a ball mill and finding the number of revolutions required to grind it so that 80% passes a 200-mesh sieve (74-microns). The *ball-mill grindability index,* in percent, is found by dividing the number of revolutions into 50,000.

In the Hardgrove test, a prepared sample receives a definite amount of grinding energy in a miniature pulverizer and the results are measured by weighing the amount passing a 200-mesh sieve. Multiplying the weight passing the sieve by 6.93 and adding 13 to the product gives the *Hardgrove grindability.* The accompanying chart makes possible approximate conversion: the table gives typical grindabilities.

Grindability values do not give a direct comparison of pulverizer capacity or power requirements. These latter are affected by the size and type of pulverizer, and by feed size, moisture, and fineness. The operator should check behavior of coals in his pulverizer against the standard indices to establish a relationship between pulverizer performance and grindability.

Caking and Coking

Considerable confusion exists regarding the proper use of the terms *caking* and *coking.* Heating coal drives off volatile matter, leaving behind practically pure carbon. This is called *coke.* It may take the form of small powdery particles or may fuse into lumps of varying sizes and strengths. Swelling may occur. In commercial coke-making, the term coke generally refers to lumps of marketable size and *coking* coals are those that will produce such a product.

Formation of coke, in one shape or another, represents an intermediate stage of combustion in any fuel-bed; the difference lies in whether or not a plastic stage occurs and lumps of coke form. Coals which become plastic and form lumps or masses of coke are called *caking* coals while those which show little or no fusing action are called *non-caking,* or *free-burning.*

The caking properties of a coal and the nature of the coke masses formed (size, strength, etc.) are now regarded as valuable indicators of behavior on a hand-fired grate or stoker fuel-bed. Current research aims at developing an index that will relate caking characteristics and the nature of the coke formed to conditions in actual fuel beds. At present, the ASTM publishes, in "ASTM Standards on Coal and Coke," a proposed method of testing for *agglutinating value,* giving an approximate measure of the material in coal which fuses and becomes plastic on heating. Something can also be learned by examining the coke buttons left after making the standard volatile-matter test. Other tests are under consideration.

Size stability is the ability of coal to resist breakage; **friability** is the opposite, the tendency of coal to break or crumble into smaller pieces under handling. Where plant conditions make size an important factor, friability must be taken into consideration to give a rough idea of the difference likely to exist between the size as shipped and the size as fired. The ASTM has set up two tentative tests for these complementary properties: the *drop-shatter test* and the *tumbler test.* The first indicates resistance to breakage from ordinary handling while the latter pictures the effect of rougher handling in mechanical conveyors, feeders, etc.

Anthracite coal comes in standard sizes, as follows: *broken* (passing a $4\frac{3}{8}$-in. screen, retained on a $3\frac{1}{4}$-in. screen), *egg* ($3\frac{1}{4}$–$2\frac{7}{16}$), *stove* ($2\frac{7}{16}$–$1\frac{5}{8}$), *chestnut,* ($1\frac{5}{8}$–$\frac{13}{16}$), *pea* ($\frac{13}{16}$–$\frac{9}{16}$), *No. 1 buckwheat* ($\frac{9}{16}$–$\frac{7}{16}$), *No. 2 buckwheat rice* ($\frac{7}{16}$–$\frac{5}{16}$), and *No. 3 buckwheat* (*barley*) ($\frac{5}{16}$–$\frac{3}{32}$). *Culm* or *river coal* is the refuse from screening anthracite into prepared sizes.

Bituminous coal comes in an almost infinite variety of sizes and there is little standardization of either screen openings or names given to sizes. *Run of mine* is unscreened coal as it comes from the mine; a steadily decreasing amount of this size is shipped today due to the demand for prepared sizes for domestic stokers, etc. Sizes are usually designated by screen openings. A "2-in. nut-and-slack" normally means all coal passing a 2-in. screen; the amount of different sizes present may vary widely. Occasionally a limitation is placed on the percentage of fines. So-called *between-screen* sizes (everything passing one screen, and retained on another) give a closer idea of size, unless the spread between screens is large.

Coal size affects the nature of the fuel bed, the draft required, the density of the coke formed and amount of unburned carbon lost up the stack.

Cleaning, Oil Treating

Many producers now offer cleaned or washed coals as products having a higher value to the user. The operator must determine by test or experience whether increased quality justifies the higher price required by increased production cost. Cleaning or washing removes impurities and so lowers ash content; it also tends to reduce sulphur in the form of pyrites. Effect on ash-fusion temperature appears to be slight.

Treating coals with refined petroleum oils of 100-600 SSU at 100 F, or blends

CHARACTERISTICS OF SOME OTHER SOLID FUELS

Fuel	Heating value, Btu.	Proximate Analysis				Ultimate Analysis							Remarks
		% Moist	% Ash	% Vol.	% FC	% H_2	% C	% N_2	% O_2	% S	% Moist	% Ash	
Wood waste	8,900*	25–60	1.0*	82.0*	17.0*	6.2*	50.3*	0.04*	43.1*	.....	.....	0.4	*Burned on flat or sloped grate in Dutch oven, or in suspension*
Peat	3,586	56.7	6.0	26.1	11.2	8.3	21.0	1.1	62.9	.....	.....	.....	*Rarley used for steam generation*
Coke	12,600*	8.5	12.5*	1.0*	86.5*	.....	.....	.....	.....	0.9	.....	.....	*Usually hand fired*
Coke breeze	9,500	6.5	25.0	3.4	65.1	.....	.....	.....	.....	.....	.....	.....	*Trav-grate-stoker fired, like anthracite culm. Can be pulverized*
Pet coke	15,550	.....	1.5	5–10*	90–95*	.....	.....	.....	.....	.....	.....	.....	*Usually pulverized*
Oil shale	6,300*	15.0	43.0	42.0	.....	.....	.....	.....	.....	.....	.....	.....	*Burned on f-d overfeed stokers*
Pulv'd pitch	16,000	0.2	0.1	53.8	46.1	4.1	93.7*	1.0*	0.7*	0.5*	0.1	0.1	*Pulverized and burned on unit system — no preheat*
Tanbark	8,000*	30–60	.....	.....	.....	6.0	50.0	40.0	.....	.....	.....	4.0	*May be dried by chimney gases*
Bagasse	8,300*	45–50	.....	.....	.....	5.8	46.3	0.3	45.8	.....	.....	1.8	*Usually burned on flat or sloped grate in Dutch oven*
Rice hulls	6,100	7.4	19.8	59.0	13.8	.....	.....	.....	.....	.....	.....	.....	*Burned in suspension — high ash means special design*
Sewage sludge	7,500	20	26.9	47.6	5.5	5.0	37.0	1.5	8.9	0.7	20.0	26.9	*Burned as cake on flat grate*
Straw	56–6700	.....	.....	.....	.....	5.0	36.0	0.5	38.0	.....	15.7	4.8	

* Indicates analysis on dry basis all others " as fired " or " as received." FC abbreviation for fixed carbon

of oil with petroleum, with wax, or with asphalt, will allay the dust nuisance in coal handling by eliminating 95 to 100% of the fine dust and 80 to 95% of the coarse. The treatment remains effective for more than a year, even in outdoor storage. Experience seems to show that such treatment reduces moisture absorption of coal and reduces difficulties with freezing. Tests on Illinois No. 5 and Pittsburgh seam coals show that oil does not increase spontaneous heating. Oil treatment, as commercially applied for dedusting, *does not appreciably* affect burning characteristics.

Ability to use cheaper small sizes without dust nuisance and handling difficulties may justify a premium price for oil-treated coal in some plants.

Storing Coal

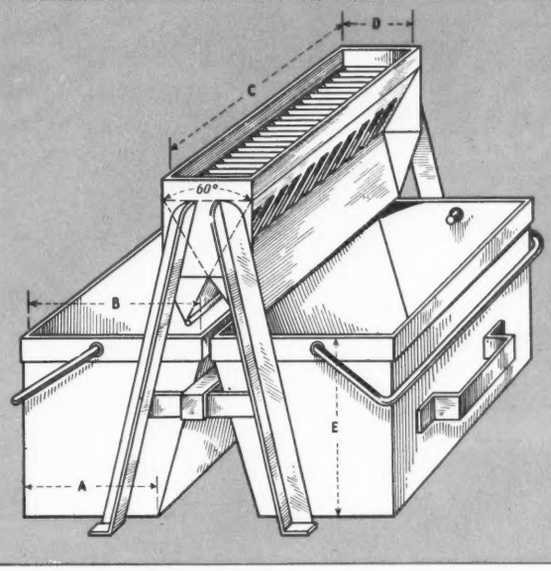
Coals exposed to the atmosphere combine with oxygen, liberating heat. This is as truly "burning" as what happens in a furnace, but when it occurs extremely slowly it is called *weathering*. Weathering dulls the appearance of coal, causes reduction in size, impairs firing and coking qualities and lowers heating value. These changes are practically unnoticeable for anthracite and slight for most bituminous coals. Low-rank bituminous coals and lignites suffer more markedly. Loss of heating value over a 5-year period might run 1-3% for West Virginia and Pennsylvania coals and 4-6% for Illinois coals.

If heat liberated by weathering is confined to a small area, a temperature rise will follow, increasing the rate of oxidation. This cycle of raising temperature and faster oxidation continues until definite "hot spots" form and *spontaneous combustion* occurs. To guard against such troubles: (1) remember that small sizes present greater surface and pack tighter, making them more likely to heat, (2) avoid piling coal in hot weather or in a heated space, (3) don't crush before piling, and watch pile closely during first 3 months of storage, since fresh surfaces oxidize more readily, (4) avoid segregation of sizes in the pile by building it up in layers, leveling off and rolling each layer, (5) check the pile regularly, especially in the region 5 to 8 ft. below the surface on the flanks—a temperature in excess of 140-150 F means the danger point has been reached and coal at that point should be withdrawn.

Coal composition varies within a given seam or mine and even between points several feet apart on the face of a seam. Although shipped from a single source, coal composition varies from car to car and from one part of a car to another. Understanding the nature of all the variations involved makes it possible to use laboratory tests and analyses intelligently and eliminates misunderstanding between buyer and seller.

SAMPLING METHOD FOR COALS CLASSED BY ASH CONTENT

	Less than 8% Ash				8.0 to 9.9% Ash				10.0 to 14.9% Ash				15.0 % Ash and Over			
	Group 1	Group 2	Group 3	Group 4	Group 1	Group 2	Group 3	Group 4	Group 1	Group 3	Group 2	Group 4	Group 1	Group 3	Group 2	Group 4
Top Size	5/8 in.	1 1/4–5/8 in.	2–1 1/4 in.	6–2 in.	5/8 in.	1 1/4–5/8 in.	2–1 1/4 in.	6–2 in.	5/8 in.	1 1/4–5/8 in.	2–1 1/4 in.	6–2 in.	5/8 in.	1 1/4–5/8 in.	2–1 1/4 in.	6–2 in.
"Commercial" Procedure																
Minimum number of increments	15	15	15	15	20	20	20	20	35	35	35	35	35	35	35	35
Minimum weight of increment, lb.	2	4	6	10	2	4	6	10	2	4	6	10	2	4	6	10
Minimum weight of gross sample, lb.	30	60	90	150	40	80	120	200	70	140	210	350	70	140	210	350
"Special Purpose" Procedure																
Minimum number of increments	75	75	75	75	100	100	100	100	175	175	175	175	175	175	175	175
Minimum weight of increment, lb.	2	4	6	10	2	4	6	10	2	4	6	10	2	4	6	10
Minimum weight of gross sample, lb.	150	300	450	750	200	400	600	1000	330	700	1050	1750	350	700	1050	1750



Large Riffle Sampler
- A = 9 in.
- B = 11 in.
- C = 20 ⅝-in. openings
- D = 5 in.
- E = 11 in.

Small Riffle Sampler
- A = 6 in.
- B = 8 in.
- C = 24 ⅜-in. openings
- D = 4 in.
- E = 8 in.

To begin with, a laboratory analysis, made according to approved standards, will represent within an extremely small margin of error the characteristics of the sample on which it is made. How well the analysis represents the lot of coal involved depends on the sampling methods employed. Until recently, the size of the gross sample was thought to be of a major importance for accurate sampling and existing ASTM standards require a 1,000 lb sample, subdivided according to a procedure carefully prescribed. Recent research shows that the accuracy of the sample depends on the number and size of the increments of which it is composed rather than on its weight. Proof of this point makes possible use of much smaller samples and simplifies the reduction of the gross sample to laboratory dimensions.

The new tentative ASTM standard distinguishes between "commercial" and "special purpose" sampling, and bases the size of the sample and number of increments on the size of the coal sampled and the expected ash content. The table above gives details. Note that *increment* refers to the quantity of coal obtained by a single sweep of the sampling instrument; where possible coal should be sampled while in motion. The standard provides for mechanical preparation of the sample and subdivision by means of large and small riffle samplers similar to those used in preparing samples in the laboratory. The commercial procedure is designed so that 95% of test results fall within plus or minus 10% of the ash content of the coal sampled (correct determination of ash value indicates correct determination of other properties).

Knowing how closely a given analysis represents a given sample and a given lot of coal, one must also know how reliable one test may be in predicting the average for a series of shipments, or, if the average quality is known, what variation might be expected in individual shipments. Recent research shows that for bituminous coals of less than 9% ash, one-half of the ash determinations will depart from the average by no more than 0.5%; for coals of more than 10% ash the deviation will be about twice as much. Common sense indicates that one test from one sample from one shipment is a poor guide; statistical studies show that an average of ten shipments is three times as accurate as a single test and an average of 20 tests is 4.5 times as accurate. Beyond 20, the gain in accuracy is small.

POWER, December, 1940 - Page 72 (788)

SPECIMEN ANALYSES OF TYPICAL COALS

Bed or Seam	State	County	%M	%V	% FC	% Ash	% S	Htg Val, Btu/lb	Ash-Fusion Temp, F
District 1:									
Bakerstown	W. Va.	Mineral	2.0	15.6	71.1	11.3	2.1	13,480	.....
		Tucker	2.6	22.0	69.2	6.2	1.3	14,210	.....
Barton	Md.	Allegany	2.5	15.8	68.3	13.4	2.1	13,020	.....
Bloss	Pa.	Tioga	2.6	20.8	66.8	9.8	1.3	13,580	.....
Brookville	Pa.	Somerset	4.3	18.0	69.0	8.7	1.2	13,340	.....
		Jefferson	2.8	34.4	52.1	10.7	3.1	13,040	.....
Clarion	Pa.	Fulton	1.5	15.2	74.8	8.5	1.2	14,100	.....
		Clarion	3.7	38.6	49.2	8.5	3.6	13,140	.....
Elk Lick	W. Va.	Mineral	1.6	16.7	66.6	15.1	3.4	12,820	.....
L Bakerstown	Md.	Garrett	2.5	17.8	67.6	12.1	0.9	13,340	.....
L Freeport	Pa.	Somerset	3.2	17.4	70.8	8.6	1.1	13,790	2500–2900
		Elk	2.8	32.8	58.4	6.0	2.0	14,120	.....
L Kittanning	Md.	Garrett	2.7	22.3	63.5	11.5	3.4	13,370	.....
L Kittanning	Pa.	Lycoming	4.1	15.9	65.3	14.7	0.5	12,320	.....
		Clarion	3.3	37.1	51.5	8.1	3.2	13,330	.....
L Sewickley	Md.	Allegany	2.8	19.6	69.8	7.8	1.1	13,910	2700–2900
M Kittanning	Pa.	Somerset	4.2	16.1	68.9	10.8	1.7	13,230	.....
		Elk	2.4	29.8	51.1	16.7	1.9	12,170	.....
Mahoning	W. Va.	Mineral	3.0	14.2	70.8	12.0	1.6	13,230	.....
Pittsburgh	Md.	Allegany	2.5	18.2	70.5	8.8	0.9	13,860	2700–3000
Redstone	Pa.	Somerset	3.3	20.2	63.6	12.9	1.7	13,010	.....
Sewickley	Pa.	Somerset	3.0	20.7	67.0	9.3	1.4	13,700	.....
U Bakerstown	Md.	Allegany	2.4	17.4	70.2	10.0	0.6	13,760	.....
U Freeport	Md.	Allegany	2.3	19.3	66.2	12.2	2.8	13,250	.....
U Freeport	Pa.	Bedford	1.1	16.4	70.8	11.7	2.1	13,630	.....
		Armstrong	3.1	33.9	54.5	8.5	2.2	13,360	2100–2600
U Freeport	W. Va.	Mineral	2.0	15.2	70.6	12.2	3.6	13,270	.....
		Tucker	2.8	24.0	65.3	7.9	1.2	13,960	.....
U Kittanning	Md.	Allegany	3.0	14.4	69.6	13.0	1.3	13,090	.....
		Clarion	3.0	38.1	50.0	8.9	5.5	13,230	.....
Waynesburg	Md.	Allegany	2.2	19.6	69.1	9.1	2.1	13,900	.....
District 2:									
Brookville	Pa.	Butler	3.7	37.0	52.4	6.9	1.6	13,550	.....
L Freeport	Pa.	Butler	3.1	35.0	55.2	6.7	1.1	13,710	.....
L Kittanning	Pa.	Armstrong	2.3	38.6	51.7	7.4	2.9	13,570	.....
Pittsburgh	Pa.	E.Westmorel'd	3.0	24.2	61.6	11.2	1.3	13,340	2600–2900
		Washington	3.0	35.7	54.4	6.9	1.2	13,710	2100–2600
Redstone	Pa.	Allegheny	3.5	32.6	52.9	11.0	1.8	12,840	.....
Sewickley	Pa.	Fayette	2.5	34.0	52.1	11.4	3.1	13,020	2200–2500
U Freeport	Pa.	Butler	3.0	34.2	53.5	9.3	1.5	13,290	2100–2700
U Kittanning	Pa.	Butler	3.4	34.7	54.8	7.1	2.0	13,510	.....
Waynesburg	Pa.	Greene	3.4	34.1	46.9	15.6	3.2	12,030	.....
District 3:									
Bakerstown	W. Va.	Preston	2.0	28.9	61.4	7.7	1.8	14,010	2200–2500
L Kittanning	W. Va.	Randolph	2.5	29.5	57.4	10.6	1.3	13,410	2600–3000
		Preston	2.5	22.9	64.3	10.3	1.8	13,450	2400–2700
Peerless	W. Va.	Webster	2.1	36.3	59.1	2.5	0.7	14,800	.....
Pittsburgh	W. Va.	Taylor	2.0	37.8	52.8	7.4	2.5	13,890	2000–2200
Redstone	W. Va.	Upshur	2.6	36.3	54.1	7.0	1.7	13,650	.....
Sewell	W. Va.	Randolph	3.3	28.8	61.9	6.0	0.8	14,060	2500–2900
Sewickley	W. Va.	Monongalia	2.0	35.6	51.0	11.4	2.5	13,080	2100–2400
U Freeport	W. Va.	Preston	2.5	29.1	57.9	10.5	1.6	13,410	2200–2800
	W. Va.	Upshur	1.5	38.0	50.7	9.8	1.4	13,550	.....
District 4:									
Brookville	Ohio	Stark	3.8	37.6	46.6	12.0	3.3	12,150	.....
Clarion	Ohio	Vinton	5.5	39.6	41.9	13.0	3.7	11,690	.....
L Freeport	Ohio	Jefferson	3.8	37.6	49.8	8.8	2.8	13,050	.....
L Kittanning	Ohio	Lawrence	7.3	37.8	45.1	9.8	1.6	11,880	.....
M Kittanning	Ohio	Perry	7.8	36.0	47.3	8.9	2.0	11,900	2200–2700
		Coshocton	5.9	41.6	44.2	8.3	3.8	12,470	.....
Pittsburgh	Ohio	Jefferson	4.5	36.8	49.6	9.1	3.0	12,740	2100–2200
		Belmont	3.8	40.3	47.2	8.7	3.9	12,940	1900–2100
Quakertown	Ohio	Jackson	9.8	32.7	53.2	4.3	0.9	12,200	.....
Redstone	Ohio	Belmont	6.7	34.8	46.8	11.7	2.3	11,990	.....
Sharon	Ohio	Jackson	12.0	30.1	43.3	14.6	0.4	10,280	.....
U Freeport	Ohio	Athens	5.1	37.3	50.8	6.8	2.8	12,590	.....
District 5:									
	Mich.	Bay	12.1	34.0	47.5	6.4	1.2	11,930	.....
		Calhoun	11.2	40.1	40.2	8.5	6.3	11,510	.....
		Midland	13.1	33.3	46.6	7.0	2.2	11,510	.....
		Saginaw	11.1	34.9	48.2	5.8	1.6	12,140	.....
		Shiawassee	11.7	36.3	42.5	9.5	2.7	11,640	.....
District 6:									
Pittsburgh	W. Va.	Brooke	4.0	36.9	50.6	8.5	2.7	12,920	2000–2200
		Hancock	5.9	35.5	49.6	9.0	2.3	12,550	.....
		Marshall	2.9	40.5	47.8	8.8	4.4	13,140	.....
		Ohio	3.5	39.5	48.7	8.3	4.2	13,030	2000–2200
District 7:									
Beckley	W. Va.	Raleigh	2.7	17.1	74.8	5.4	0.7	14,390	2500–3000
Big Eagle	W. Va.	McDowell	3.0	29.2	62.0	5.8	0.8	14,150	.....
Bradshaw	W. Va.	McDowell	2.5	22.1	70.0	5.4	1.0	14,540	.....
Campbell Creek	W. Va.	Fayette	2.6	32.6	59.4	5.4	1.2	14,070	2400–2800
Coalburg	W. Va.	Fayette	1.8	34.4	58.0	5.8	0.7	14,050	.....
Eagle	W. Va.	Fayette	2.5	29.7	62.3	5.5	0.6	14,360	2400–3000
Fire Creek	W. Va.	Raleigh	2.7	16.4	74.7	6.2	1.0	14,260	2400–2800
Jewell	Va.	Buchanan	2.6	20.8	73.2	3.4	0.5	14,870	.....
Langhorne	Va.	Pulaski	3.6	10.8	66.7	18.9	0.5	11,840	.....
L Seaboard	Va.	Tazewell	3.1	27.3	65.7	3.9	1.0	14,650	.....
Merrimac	Va.	Montgomery	2.4	11.5	66.7	19.4	0.6	12,000	2400–3000
Pocahontas No. 3	Va.	Tazewell	3.2	19.9	72.5	4.4	0.6	14,570	2200–2600
Pocahontas No. 3	W. Va.	McDowell	2.7	17.6	73.7	6.0	0.7	14,440	2200–2700
	W. Va.	Raleigh	2.6	16.4	74.1	6.9	0.7	14,210	2600–2900
Pocahontas No. 4	W. Va.	McDowell	1.9	15.9	75.4	6.8	0.5	14,370	2100–2400
Pocahontas No. 5	Va.	Tazewell	3.4	21.0	69.4	6.2	0.5	14,200	.....
Pocahontas No. 6	W. Va.	Wyoming	2.0	17.9	74.6	5.5	0.6	14,520	2500–2900
		Greenbrier	3.0	22.6	68.6	5.8	0.5	14,350	.....
Powellton	W. Va.	Fayette	3.1	32.0	59.4	5.5	0.7	14,130	.....
Raven	Va.	Tazewell	2.2	30.9	59.7	7.2	0.6	14,060	.....
Red Ash	W. Va.	McDowell	1.5	23.8	70.0	4.7	0.8	14,890	.....
Sewell	W. Va.	McDowell	3.0	18.1	72.9	6.0	0.6	14,300	2400–2600
		Greenbrier	3.1	25.0	66.8	5.1	1.3	14,290	2200–2500
Welch	W. Va.	McDowell	2.5	18.2	72.2	7.1	0.5	14,180	2500–2900
District 8:									
Alma	W. Va.	Boone	2.8	35.2	54.0	8.0	1.7	13,540	.....
Big Eagle	W. Va.	McDowell	2.9	31.2	59.6	6.3	1.8	14,050	.....
Big Mary	Tenn.	Anderson	2.5	36.8	51.6	9.1	3.3	13,230	2200–2500
Bingham	Ky.	Pike	4.2	33.7	53.6	8.5	2.2	13,430	.....
Blair	Va.	Wise	2.9	32.7	58.7	5.7	0.9	14,060	.....
Campbell Creek	W. Va.	Fayette	2.5	34.7	56.5	6.3	1.0	14,000	2400–2600
Cedar Grove	W. Va.	Logan	2.0	35.7	56.0	6.3	1.6	13,950	2300–2900
Chilton	W. Va.	Logan	2.5	34.4	56.9	6.2	0.7	13,910	2500–2900
Clintwood	Va.	Buchanan	2.5	31.3	59.6	6.6	1.1	14,110	2600–3000
Coalburg	W. Va.	Kanawha	3.5	34.2	54.9	7.4	0.8	13,470	.....
Coal Creek	Tenn.	Anderson	2.0	36.3	55.3	6.4	1.2	13,910	2200–2500
		Morgan	2.0	39.0	51.9	7.1	3.9	13,860	2000–2200
Dean	Ky.	Knox	4.0	36.0	52.7	7.3	0.9	13,150	2600–2900
Deep River	N. C.	Lee	2.0	32.1	58.3	7.6	2.5	13,750	.....
		Moore	3.7	15.9	57.9	22.5	3.0	11,280	.....
Dorchester	Va.	Wise	2.6	32.0	58.5	6.9	1.4	13,910	.....
Eagle	W. Va.	Logan	2.5	32.7	58.6	6.2	0.8	13,980	2600–2900
Elkhorn	Ky.	Letcher	3.0	36.4	57.3	3.3	0.5	14,170	2200–2600
Fire Clay No. 4	Ky.	Perry	3.5	37.3	54.8	4.4	0.8	13,820	2300–2800
Harlan	Ky.	Harlan	2.5	37.1	55.8	4.6	0.8	14,000	2300–2800
Hazard No. 4	Ky.	Breathitt	5.6	34.0	53.3	7.1	1.0	12,960	.....
Hazard No. 6	Ky.	Perry	4.8	35.2	53.0	7.0	0.6	13,090	2900–
Hazard No. 7	Ky.	Perry	4.3	35.7	54.1	5.9	0.6	13,430	2800–3000
Hernshaw	W. Va.	Boone	3.0	34.6	57.3	5.1	0.9	14,160	.....
High Splint	Ky.	Harlan	4.0	37.6	53.7	4.7	0.7	13,500	2300–2700
Hooper	Tenn.	Morgan	2.6	37.4	56.5	3.5	1.5	14,020	.....
Horse Creek	Ky.	Clay	5.2	35.9	52.4	6.5	1.3	13,360	.....
Imboden	Va.	Wise	2.5	34.3	56.7	6.5	0.8	13,820	2500–2900
Jellico	Tenn.	Campbell	4.0	36.5	54.8	4.7	1.0	13,760	2300–2800
Keokee	Ky.	Harlan	3.0	36.9	56.6	3.5	0.7	14,120	2200–2500
L Banner	Va.	Buchanan	2.3	32.3	57.8	7.6	1.3	14,150	2600–2800
		Russell	2.1	36.3	55.3	6.3	0.7	14,090	.....
L Elkhorn	Ky.	Pike	3.0	33.2	57.3	6.5	0.6	13,880	2600–3000
L Kittanning	W. Va.	Kanawha	3.0	35.2	53.7	8.1	0.8	13,330	2500–2900
L Sewanee	Tenn.	Cumberland	2.3	28.3	62.1	7.3	0.7	13,750	.....
Low Splint	Va.	Lee	2.9	36.4	53.7	7.0	0.7	13,630	.....
Mason	Ky.	Bell	3.0	37.4	55.4	4.2	1.2	13,920	2400–2600
Millers Creek	Ky.	Johnson	5.0	37.1	54.3	3.6	1.7	13,450	.....
Norton	Va.	Wise	2.9	32.9	57.6	6.6	1.1	13,910	.....
No. 1	Ky.	McCreary	3.1	36.3	53.0	7.6	2.6	13,300	.....
No. 1½	Ky.	McCreary	4.0	35.6	54.1	6.3	0.6	13,330	.....
No. 7	Ky.	Boyd	5.0	37.3	51.8	5.9	1.0	12,790	.....
Peewee	Tenn.	Anderson	3.2	37.6	54.2	5.0	1.0	13,840	.....
Phillips	Va.	Lee	3.2	35.5	54.1	7.2	1.0	13,310	.....
Pittsburgh	W. Va.	Mason	4.3	41.3	44.3	10.1	3.4	12,420	.....
Poplar Creek	Tenn.	Campbell	3.0	36.9	55.3	4.8	1.4	13,780	.....
Poplar Lick	Ky.	Bell	3.4	37.9	49.7	9.0	2.6	13,120	.....
Powellton	W. Va.	Fayette	2.5	32.7	60.3	4.5	0.8	14,280	2600–2900
Raven	Va.	Tazewell	2.8	31.7	59.7	5.8	0.5	14,240	.....
Red Ash	Tenn.	Campbell	3.4	38.5	52.2	5.9	1.1	13,510	.....
Splash Dam	Va.	Dickenson	1.9	30.7	59.7	7.7	0.9	14,060	.....
Sterling	Ky.	Bell	2.2	37.9	50.5	9.4	3.0	13,060	.....
Stockton	W. Va.	Kanawha	3.1	36.1	54.9	5.9	0.6	13,790	.....
Straight Creek	Ky.	Bell	3.0	37.9	54.6	4.5	0.8	13,930	2100–2300
Taggart	Va.	Lee	3.3	35.7	56.6	4.4	0.6	13,960	2100–2500
U Banner	Va.	Dickenson	2.0	30.0	62.0	6.0	0.8	14,400	2400–2800
		Russell	2.7	35.0	55.3	7.0	0.6	13,870	2200–2500
U Elkhorn No. 1	Ky.	Floyd	4.0	36.8	54.2	5.0	0.9	13,580	2300–2700
U Elkhorn No. 2	Ky.	Floyd	4.4	35.9	54.6	5.1	1.1	13,530	2200–2700
U Elkhorn No. 3	Ky.	Pike	3.3	33.4	58.4	4.9	0.7	13,900	.....
Wallins	Ky.	Harlan	3.1	38.1	54.3	4.5	0.7	13,840	.....
Warfield	Ky.	Martin	3.0	39.1	50.7	7.2	2.3	13,290	2200–2300
Wilder	Tenn.	Overton	3.3	35.8	50.5	10.4	2.5	12,880	2100–2400
Windrock	Tenn.	Anderson	2.5	38.0	52.7	6.8	0.9	13,620	.....
Winifrede	W. Va.	Mingo	3.5	36.1	53.8	6.6	0.6	13,550	2600–3000
District No. 10:									
Herrin No. 6	Ill.	Christian	13.5	35.6	39.3	11.6	4.2	10,610	2000 approx
		Franklin	9.5	33.0	49.0	8.5	0.8	11,900	2100–2500
		Fulton	17.0	34.0	42.2	6.8	2.6	10,960	.....
		Bond	12.4	32.9	42.9	11.8	4.0	10,730	.....
		Jefferson	8.9	34.2	48.2	8.7	1.3	11,930	.....
LaSalle No. 2	Ill.	Bureau	15.7	35.0	38.9	10.4	3.8	10,580	.....
Springfield No. 5	Ill.	Peoria	14.5	34.1	39.0	12.4	3.0	10,530	.....
Harrisburg No. 5	Ill.	Saline	6.5	33.9	51.2	8.4	2.2	12,490	2000–2100
Colchester No. 2	Ill.	Henry	14.5	37.1	38.7	9.7	3.3	10,750	.....
Rock Island No. 1	Ill.	Knox	14.5	37.2	38.6	9.7	5.1	10,970	.....
Danville No. 7	Ill.	Vermilion	13.3	36.6	39.0	11.1	3.6	10,940	.....
District No. 11:									
III	Ind.	Greene	11.2	36.7	43.7	8.4	4.0	11,570	.....
IV	Ind.	Clay	11.9	34.7	44.1	9.3	1.7	11,440	.....
V	Ind.	Sullivan	11.8	34.1	47.6	6.5	1.3	11,850	.....
		Warrick	10.0	37.4	43.1	9.5	3.9	11,570	2000–2200
VI	Ind.	Sullivan	11.9	35.8	43.7	8.6	2.2	11,590	.....
VII	Ind.	Sullivan	15.2	31.7	44.8	8.3	0.6	11,150	.....
Brazil Block	Ind.	Clay	16.0	31.3	46.5	6.2	1.0	11,460	.....
Semi-Block	Ind.	Greene	10.9	40.3	41.3	7.5	2.9	12,010	.....
Minshall	Ind.	Vermilion	12.3	37.6	39.0	11.1	4.6	11,010	.....
		Vigo	13.1	37.7	40.7	8.5	2.4	11,410	.....
District No. 13:									
Yeshic	Ala.	Bibb	4.4	31.7	47.7	16.2	1.3	11,620	.....
Clark	Ala.	Bibb	2.9	34.8	56.1	6.2	0.8	13,830	2100–2400
Jagger	Ala.	Fayette	3.1	33.9	52.5	10.5	0.7	12,790	.....
Battle Creek	Ala.	Jackson	2.9	34.4	52.7	10.0	1.2	13,210	.....
Black Creek	Ala.	Jefferson	2.9	31.8	61.5	3.8	0.7	14,410	2500–2800
Black Creek	Ala.	Marion	5.1	37.3	54.4	3.2	1.4	13,640	.....
Helena	Ala.	St. Clair	3.9	34.2	56.0	5.9	1.0	13,580	.....
Montevallo	Ala.	Shelby	2.9	38.4	52.8	5.9	0.8	13,700	.....
Blue Creek	Ala.	Tuscaloosa	4.7	24.4	61.7	9.2	0.6	13,360	.....
Brookwood	Ala.	Tuscaloosa	3.3	31.0	52.8	12.9	1.5	12,450	.....
Mary Lee	Ala.	Walker	3.6	30.9	53.0	12.5	0.8	12,320	2600–2900
Corona	Ala.	Walker	2.6	38.1	49.4	9.9	2.3	12,950	.....
Etna	Ga.	Dade	3.5	27.2	64.0	5.3	1.0	14,250	.....
Durham No. 5	Ga.	Walker	3.1	20.0	70.5	6.4	1.0	14,190	.....
Durham No. 4	Ga.	Walker	3.2	19.5	67.6	9.7	0.8	13,610	.....
Sewanee	Tenn.	Grundy	3.3	29.7	58.0	9.0	0.6	13,260	2300–2700
U Clifty	Tenn.	Hamilton	2.8	29.7	57.6	9.9	2.5	13,430	.....
Nelson	Tenn.	Rhea	1.9	31.8	58.0	8.3	0.7	13,700	.....

The above data is condensed from more comprehensive information recently compiled by the Bureau of Mines, in cooperation with the Consumer's Counsel, Bituminous Coal Division. In the original data, a specimen analysis, selected as typical by use of frequency curves, is given for each bed or seam in each county, state, and producing district. This table gives a single specimen analysis for typical seams in each producing district; where a seam shows a wide range of characteristics, two specimen analysis are included, comprising, in most cases, the high and low volatile percentages recorded in the data. Fusion temperatures show usual range encountered. These analyses are from run-of-mine samples; screenings would probably show slightly more ash and prepared coals would should slightly less ash and sulphur and higher heating value.

Only coals from fields east of the Mississippi are included; other analyses are in preparation. All will be published in a series of "data books" to be issued by the Consumer's Counsel, Bituminous Coal Division, Dept of the Interior.

BITUMINOUS COALS AVAILABLE

This table shows 1937 all-rail shipments from producing districts to market areas.

Market Area	PRODUCING DISTRICTS 1	2	3	4	5	6	7LV	7HV	8LV	8HV	9	10	11	12	13	14	15	16	17	19	20	22
1	590	71	125				6		✓	5												
2	10,161	3,191	5,056			60	292	1	7	417												
3	269	53	34			1	1,208	8	21	48												
4	1,236	2,215	477	98		113	35			3												
5	116	72	13	4		16	✓			2												
6	1,413	173	43			✓	37			1												
7	532	2,810	122	3		4	14			2												
8	✓	1	663			2	36		✓	1												
9	4	22	6	3		114	82			9												
10	3	687	78	35		11	32			18												
11	117	3,424	124	590		77	526		✓	60												
12	1	256	536	124		57	138		✓	220												
13	28	2,301	958	4,276		73	2,411	3	41	884												
14	✓		5	484			6			13												
15	2	57	56	805		3	618	8	38	2,197		1	✓									
16	✓	3	26	107			32	1	3	263												
17	1	13	47	860		5	53	10	9	818												
18	✓	1	2	127			48	1	8	453												
19	1	5	52	158		✓	1,321	7	78	3,929		✓										
20	✓	12	14	84	80	✓	145	2	22	1,096		11	5									
21	5	94	188	924	21	✓	3,071	14	94	7,848	✓	35	22									
22	✓	✓	3	25			176	5	4	553		10	89									
23	✓	2	12	50			121	7	11	1,209	1	121	492									
24	✓		2	1			44	2	3	264	1	2	108									
25		✓	1	1			36	1	2	93		✓	65									
26			✓				4	✓	1	105			27									
27				1			3		✓	52	✓	✓	85									
28	✓	✓	3	✓			402	37	5	645	2	6	1,370									
29	19	2	43	✓			4,810	4	138	3,098	391	7,493	2,147		✓							
30	✓	✓	12	7			2,475	5	17	2,958	7	473	1,135									
31							2		✓	102	48		64									
32	1		✓	✓			26	1	1	127	26	33	659		✓							
33	✓		1				109			94			521									
34	✓						1			2	62		315									
35	1						25		✓	6	23	838	84		✓						✓	
36										✓		11	1									
37	✓						✓			5	1	16	9									
38	2	✓	5	7			22		2	344	40	3,730	146			✓	2					
39	✓						✓			3	✓	125	✓									
40	3		2				134		1	225	70	4,367	49		✓	6						
41	1	✓	130	3			1,010	✓	15	524	206	3,571	609			✓						
42	1		3	✓			424	✓	10	60	172	1,100	400									
43	3	✓	4	1			215		6	62	27	247	78			✓						
44	✓	✓	✓	8			34		1	27	✓	2	1									
45	2		✓				11		✓	18	18	174	13	1		11	1		1	✓		7
46	2		1	✓			98		7	67	43	391	63	4		83	1			✓		2
47	✓		1	2			2			191	25	98	9	79		7	3		2	✓	✓	✓
48	✓		✓	✓			1		✓	25	2	28	5	12			✓					
49	✓		1	✓			6		1	148	25	150	66	109		1	✓					
50	1		6	✓			52	1	3	329	82	742	182	100		1	6			1		
52	✓		✓				✓			11	14	66	8									
53	✓		✓				1		✓	30	26	153	6	33		✓	✓					
54	✓						✓			4	9	93		✓			✓					
55	✓		1	✓			3		✓	130	16	130	16	213		9	6		7	1	✓	
56	✓						✓			1	2	23	1	11		76	76		1	2	✓	
57							✓			4	1	16	✓	4		5	6		1	✓	✓	....
58	1									1	5	42	✓	7		270	570	✓	1	9	✓	
59	✓						✓			16	2	46	✓	30		4	4		✓	✓		
60										10	8	5	✓	5								
61										1		✓		✓								
62	✓		✓	✓			✓			19	4	16	5	4		✓						
63	✓						✓		1	16	4	13	9	194		✓	8					
64	✓						✓			7	4	8	1	4		✓	✓					
65	✓		✓	✓					✓	5	1	8	5	34		✓	✓					
66	✓									8	2	74	2	45		8	10		✓	✓		
67										1		1	✓	1								
68	✓						✓			4	6	80	✓	1			1					
69	✓						✓			✓	2	54		1		53	127			✓		
70	✓									2	1	174	4	✓	✓	8	227					
71	✓									✓	1	119					4					
72	✓						✓			✓	1	137	✓			7	52					
73	✓						✓				20	347			3	✓						
74	1						✓			✓	5	24			2	49	167		✓			
75	1										✓	2	✓			374	1,405		✓			
100	1		15				3,271	51	122	801												
101			✓				222	3		1,666					✓							
102							26	1	3	851	2		✓									
103							12	✓	✓	830	349		19		2							
104							1			133	743	5			51							
105							621	38	119	619												
106							5		1	1,049	✓											
107							180	20	23	620												
108							206	8	11	342					✓							
109							26	1		1,984					14							
110							3			658												
111							✓			619	✓				1							
112							18			381					147							

Market Area	PRODUCING DISTRICTS 1	7LV	7HV	8LV	8HV	9	10	11	12	13	14	15	16	17	18	19	20	22	23
113					50	18				127									
114		✓			252	819				18									
115					12	127	✓			35									
116		✓			94	416	6			50									
117					10	1				34									
118					44					18									
120					✓					13									
121					2					85									
122					17					39									
123					20					38									
124					✓					13									
125		✓			232					8									
126		3		✓	1,367					63									
127		22	27	3	153														
128					2					1									
129					135					4									
130					13					29									
131					7					2									
132					1					57									
133					1					✓									
134					✓					✓									
135					5					✓									
136					2					✓									
137					1														
138					32					58									
139					38					28									
140					9					9									
141					22					2									
142					6					11									
143		1			✓					19									
144					✓					4									
145					3					18									
146					2					28									
147		120			10	2	✓			1,491									
148					6	11	1			166									
149						✓				3									
150					3	6	✓			36									
151					✓	94	4			35									
152		✓			1	136	6			113									
153		✓			1	42	10			134	2	✓							
154		✓				10	2			1	5	✓							
155	✓	✓				1	✓			1	45	1							
156		✓			2	43	6			21	25	✓							
157	✓				✓	37	34			14	4	✓							
200	1	3		✓	2	13	27	✓	✓		9	✓		2		3		77	
201	✓	9		✓	9	11	96	1	2		54	16		13		7	✓	24	
202	✓	✓			1	1	1	✓	✓		1	1		16		5	✓	1	
203	✓										✓			2		92			
204	✓	✓			2	3	67	1	✓		56	82	✓	42		29	3		
205	1				1	2	32	1			22	84	6	376		175	6		
206	✓					3	1				✓	1	✓	58		94	1		
207	✓						10	✓			59	87		2		1			
208	1	✓					18			✓	119	429	✓	85		6	4		
209	✓						1				16	55							
210	✓						✓				16	83	✓	118		3	5		
211	✓						✓				27	45		3					
212	1	✓				2	✓			9	127	520		39					
213	✓	✓					✓									47	26	331	
214	✓															26		50	
215	✓												5	26		239		✓	
216																45	✓		
217	1												604	141		9	✓		
218	✓												740	293		✓			
219	✓												11	126					
220												✓	✓	854					
221														✓					
222														46					
223														41					
224	✓													77			2		
225														4					
226											1	1	✓	88	4				
227														4	12				
228										✓	2	9		72	9				
229										✓		1		3	1				
230														1	✓				
231	✓													3	41				
232	✓										✓	✓		22	66				
234	✓													1		25	1,067		
235																			
236	✓											✓		2	188				
237	1	✓												2		162	695	9	764
238														✓			1	1	6
239	✓													2		74	57	9	29
240	✓													1		31	94		42
241	✓													9	11	55	740		✓
242	3															✓			1
243																		✓	94

Lake, Tidewater, and River Coal Shipments

Lake Shipments:

Districts 1, 2, 3, 4, 6, 7, 8, to Lake Erie ports

Districts 1, 2, 3, 6 to Lake Ontario ports

Tidewater Shipments:

Districts 1, 2, 3, 7, 8 to Eastern tidewater ports

River Shipments:

Districts 1, 2, 3 to market areas 7, 9, 13

District 4 to market areas 13, 14, 19

District 6 to market areas 7, 8, 9, 11, 13, 14

District 8 HV to market areas 7, 17, 19, 26, 31, 34, 38, 46, 101, 102, 103, 104

District 9 via Ohio River, southern Mississippi

District 10 to St. Paul, Minneapolis, Chicago, Cape Girardeau, Mo.

District 13 to market area 147

Ex-River Shipments:

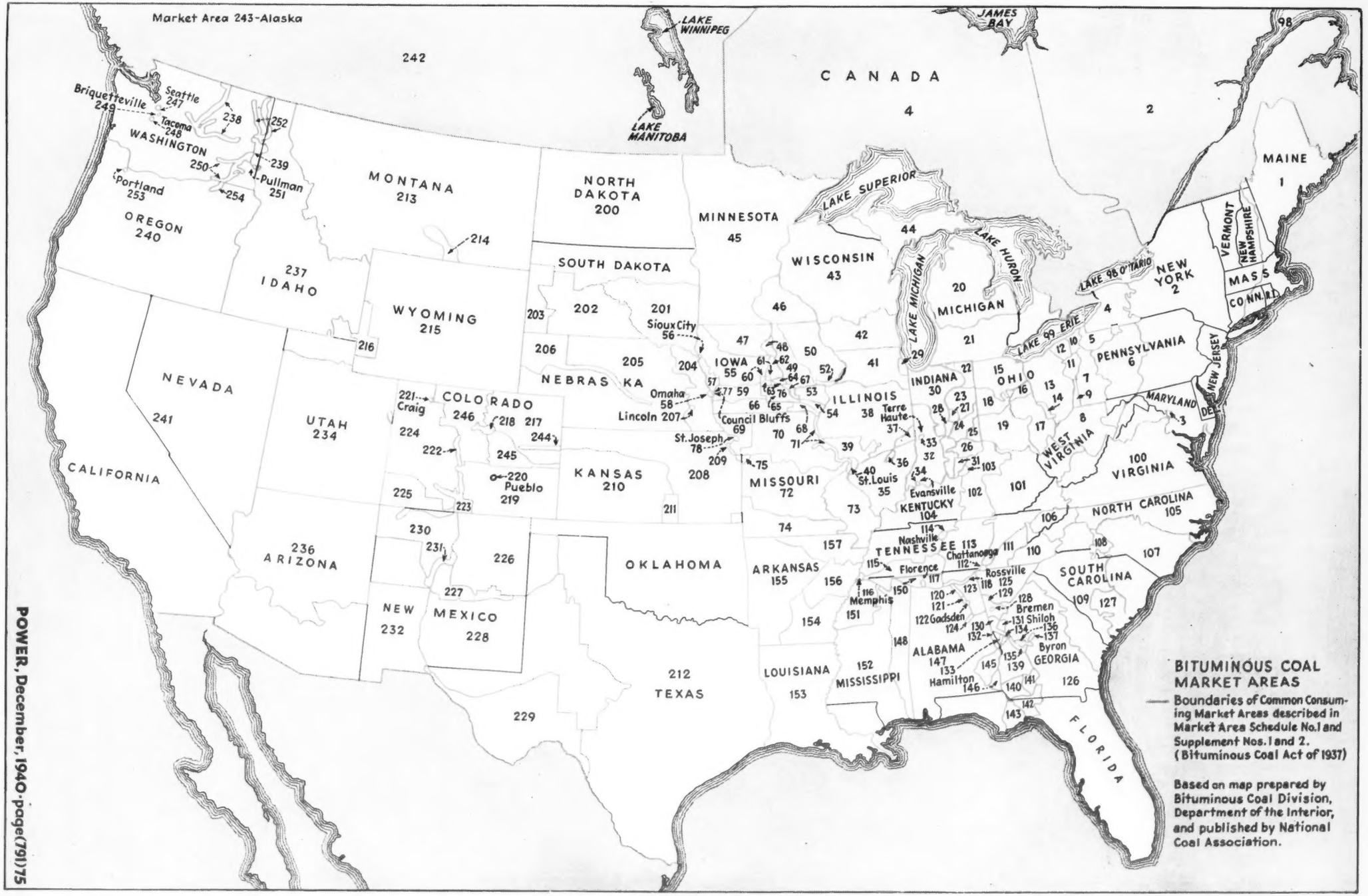
District 2 to market areas 7, 11, 13,

District 3 to market areas 7, 11,

District 6 to market areas 4, 11, 12, 13, 15

District 8 HV to market areas 7, 12, 13, 15, 17, 18, 19, 22–34, 38, 41, 102

Notes: Tonnages given to nearest thousand; check mark indicates shipment of less than 500 tons. The figures given include all sizes of bituminous coal shipped by rail, excluding railroad fuel and unpriced coal. Distribution by lake, river, and tidewater is indicated generally in the inset. Designations HV and LV refer to high- and low-volatile, respectively. Districts and areas as defined by the Bituminous Coal Act of 1937.



BITUMINOUS COAL MARKET AREAS

— Boundaries of Common Consuming Market Areas described in Market Area Schedule No. 1 and Supplement Nos. 1 and 2. (Bituminous Coal Act of 1937)

Based on map prepared by Bituminous Coal Division, Department of the Interior, and published by National Coal Association.

POWER, December, 1940 · page (79) 175

Liquid and Gaseous Fuels

PETROLEUM and its byproducts furnish practically all the commercially used liquid fuels. Geologists believe that decomposition of minute marine growths, or possibly of vegetable matter in some cases, formed the oil which lies trapped in pools between layers of the earth's crust. This *crude oil* consists of complicated combinations of carbon and hydrogen called *hydrocarbons*. Crudes from the Appalachian field (see map) are rich in a class of hydrocarbons called paraffin compounds; these crudes are said to be *paraffin-base* oils. In western fields another family of hydrocarbons dominates, making these crudes *asphalt-base* oils. Crudes of the Mid-Continent field contain both hydrocarbon groups and so are called *mixed-base* oils.

Crude oil moves from well to refinery by pipeline in most cases; most refinery capacity lies near producing fields. Although every state boasts some local refining capacity, ten states account for 90% of the nation's total. Texas, with 1,389,595 bbl daily capacity, leads with almost 30% of the total, while California (935,910 bbl daily) comes in second with 20%. The remaining eight, in order of importance, are: Pennsylvania (308,100 bbl), New Jersey (255,950), Illinois (251,850), Indiana (242,750), Oklahoma (228,375), Louisiana (210,250), Kansas (169,970), and Ohio (167,000). Fuel oils move into nearby markets by truck and tank car; coast-wise tankers serve the seaboard areas.

Kinds of Fuel Oil

Since practically all fuel oils are either products or byproducts of refining, the way they are made has more to do with their fuel qualities than the source of the crude. Fuel oils can be grouped into four general classes: *topped crudes, distillates, residuals,* and *refinery wastes.* "Topping" takes out gasoline, kerosene, and gas oil, leaving an oil suited to fuel use. Because this extremely simple process results in a small yield of the more valuable products, it is rarely employed today. If the crude is subject to complete distillation, oil suited for fuel purposes will be distilled off between the kerosene and lubricating-oil fractions. This *distillate* oil, because of its purity and superior characteristics, commands a good price as diesel-engine fuel and for use in oil-burners not able to handle heavier oils.

Residual oils, as the name implies, are what is left after distilling off most of the lighter parts of the crude. Being literally "left-overs," they usually contain heavy tars and impurities. Thermal cracking, a refining process designed to increase the yield of gasoline, produces a residual oil likely to be even heavier than that resulting from the older processes. The newest refining processes (Houdry, or catalytic cracking) produce no residual oil at all, only a small quantity of tar. This development carries possibilities of serious shifts in the fuel-oil picture.

At the moment, residual oils that form the bulk of liquid fuel used for steam generation constitute a byproduct and

TABLE I—OIL MEASUREMENTS AT 60 F

Gravity deg, API	Specific gravity	Lb per gal	Btu per lb	Btu per gal	Lb per 42-gal barrel	Weight lb per cu ft
3	1.0520	8.76	18,190	159,340	368.00	65.54
4	1.0443	8.69	18,240	158,500	365.31	65.07
5	1.0366	8.63	18,290	157,840	362.62	64.59
6	1.0291	8.57	18,340	157,170	359.98	64.12
7	1.0217	8.50	18,390	156,320	357.37	63.65
8	1.0143	8.44	18,440	155,340	354.81	63.19
9	1.0071	8.39	18,490	155,130	352.46	62.78
10	1.0000	8.33	18,540	154,620	350.15	62.36
11	0.9930	8.27	18,590	153,740	347.71	61.93
12	0.9861	8.22	18,640	153,220	345.28	61.50
13	0.9792	8.16	18,690	152,510	342.88	61.07
14	0.9725	8.10	18,740	151,790	340.53	60.65
15	0.9659	8.05	18,790	151,260	338.22	60.24
16	0.9593	7.99	18,840	150,530	335.91	59.83
17	0.9529	7.94	18,890	149,980	333.64	59.42
18	0.9465	7.89	18,930	149,360	331.42	59.03
19	0.9402	7.83	18,980	148,610	329.23	58.64
20	0.9340	7.78	19,020	147,980	327.05	58.25
21	0.9279	7.73	19,060	147,330	324.91	57.87
22	0.9218	7.68	19,110	146,760	322.81	57.49
23	0.9159	7.63	19,150	146,110	320.71	57.12
24	0.9100	7.58	19,190	145,460	318.65	56.75
25	0.9042	7.53	19,230	144,800	316.59	56.39
26	0.8984	7.49	19,270	144,330	314.58	56.03
27	0.8927	7.44	19,310	143,670	312.60	55.68
28	0.8871	7.39	19,350	142,990	310.63	55.32
29	0.8816	7.35	19,380	142,440	308.70	54.98
30	0.8762	7.30	19,420	141,770	306.81	54.64
31	0.8708	7.26	19,450	141,210	304.92	54.31
32	0.8654	7.21	19,490	140,520	303.03	53.97
33	0.8602	7.17	19,520	139,960	301.18	53.64
34	0.8550	7.12	19,560	139,270	299.37	53.32
35	0.8498	7.08	19,590	138,690	297.57	53.00
36	0.8448	7.04	19,620	138,120	295.80	52.68
37	0.8398	7.00	19,650	137,550	294.04	52.37
38	0.8348	6.96	19,680	136,970	292.32	52.06
39	0.8299	6.92	19,720	136,460	290.64	51.76
40	0.8251	6.87	19,750	135,680	288.91	51.46
41	0.8203	6.83	19,780	135,090	287.23	51.16
42	0.8156	6.79	19,810	134,510	285.55	50.86

The above relation between specific gravity and API degrees is expressed by the formula

$$\frac{141.5}{131.5 \text{ deg} + \text{API deg}} = \text{Specific gravity at 60 F}$$

For each 10F above 60F add 0.7 deg API
For each 10F below 60F substract 0.7 deg API

TABLE II—CHARACTERISTICS OF GASEOUS FUELS

Fuel	Source	Avg Composition	High Heat Value, Btu/cu ft	Remarks
Blast-furnace gas	Byproduct of iron making	58% N_2, 27% CO, 12% CO_2, 2% H_2, some CH_4	90–100	Good fuel when cleaned — used mainly at source
Butane	Byproduct of gasoline making, also in casing-head gas	C_4H_{10} (usually has some butylene C_4H_8 and propane C_3H_8)	3200–3260	Liquifies under slight pressure, sold as liquid
Casinghead gas	Oil wells	Varies, mostly butane & propane	1200–2000	Used mostly in oil fields
Carburetted water gas	Manufactured from coal, enriched with oil vapor	35% H_2, 34% CO, 15% CH_4, 13% C_2H_4, 2% N_2, 1% CO_2	500–600	Good fuel, but usually costly. Part of most city gas
Coke-oven gas	Byproduct coke ovens	48% H_2, 32% CH_4, 8% N_2, 6% CO, 3% C_2H_4, 2% CO_2, 1% O_2	500–600	Good fuel when cleaned, often used at source
Natural gas	Gas wells	Varies, mostly CH_4, C_2H_6, C_3H_8	950–2200	Ideal fuel, piped to point of use
Oil gas	Manufactured from petroleum	54% H_2, 27% CH_4, 10% CO, 3% N_2, 3% CO_2, 3% C_2H_4	500–550	Used on West Coast, often mixed with coke-oven gas
Producer gas	Manufactured from coal, coke, wood, etc	59% N_2, 22% CO, 11% H_2, 6% CO_2, 2% CH_4	135–165	Requires cleaning
Propane	Byproduct of gasoline	C_3H_8	2500	Similar to butane
Refinery gas	Byproduct of petroleum processing	Varies, mostly butane and propane	1200–2000	Used mainly at refineries, some piped
Sewage gas	Sewage-disposal plants	65% CH_4, 30% CO_2, 2% H_2, 3% N_2, traces of O_2, CO, H_2S	600–700	Many disposal plants meet all power needs with this fuel

the supplies available depend largely on the demand for gasoline. Widespread use of processes in which fuel oil must be produced deliberately, instead of some other product, might change the economics of the situation completely. At present only about 10% of refinery capacity works on the Houdry or catalytic processes. The influence of changing refinery methods shows in these figures: in 1920, 42% of crude processed came on the market as bunker fuel while today it's 25%.

Refinery wastes have little or no commercial value and are usually burned at the refinery or in adjacent plants. They include *acid sludge*, which results from using sulphuric acid to remove tarry or gummy constituents from oil; *tars*, which may include some sludges from acid cleaning operations or distillation residues; *tank cleanings* or *bottoms* which include oil of varying gravity and volatility, dirt, water, salts, asphaltic and waxy semi-solid materials, and often iron scale.

Fuel oil, like the crude from which it is made, consists mostly of carbon and hydrogen, with a few percent of oxygen, nitrogen and sulphur. Hydrogen has a much higher heating value and lower atomic weight than carbon; it's easy to see that the proportions of carbon and hydrogen will affect both the specific gravity and the heating value of the oil. Because of this, specific gravity forms a reliable guide to an oil's heat content, see Table I.

Specific gravity in *degrees API* (American Petroleum Institute) is found by dividing the *specific gravity with respect to water* (at 60 F) into 141.5 and subtracting 131.5 from the answer. Gravity in *degrees Baumé* is found the same way except the numbers are 140 and 130. For practical engineering work, the two gravity scales may be considered the same.

Viscosity

The relative ease or difficulty with which an oil flows is called its *viscosity*. It is measured by the time in seconds a standard amount of oil takes to flow through a standard orifice in a device called a viscosimeter. Various viscosimeters find use but the usual standard in this country is the *Saybolt Universal* or the *Saybolt Furol* for oils of high viscosity. Since viscosity changes with temperature, viscosity tests must be made at a standard temperature, usually 100 F for Saybolt Universal and 122 F for Saybolt Furol.

Viscosity indicates how oil will behave when pumped and, more particularly, shows when preheating is required and what temperature must be maintained.

Flash point represents the temperature at which an oil will give off enough vapor to make an inflammable mixture with air. The result of a flash-point test depends on the apparatus used, so this must be specified as well as the temperature. The *Cleveland open cup* and the *Pensky-Martens closed cup* are the usual methods. Flash point measures volatility of oil and indicates maximum temperature for safe handling.

The *pour point* represents the lowest temperature at which an oil will flow under standard conditions. Including pour point in a specification insures getting an oil that will not cause handling trouble at expected low temperatures.

By centrifuging a sample of oil, the amount of *water and sediment* can be found. These are impurities, and while it is not economical to eliminate them, they should not occur in excessive quantities (not more than 2%). Incombustible impurities in oil, from natural salts, from chemicals used in refinery operations, or from rust or scale picked up in transit, show up as *ash*. Some ash-producing impurities cause rapid wear of refractories and some are abrasive to pumps, valves and burner parts. The *carbon-residue* test (sometimes called *Conradson carbon*) indicates carbon-forming tendencies and may permit detection of heavy residual products in blended oils.

All the tests mentioned above are covered by ASTM standards which should be consulted for details of apparatus and methods.

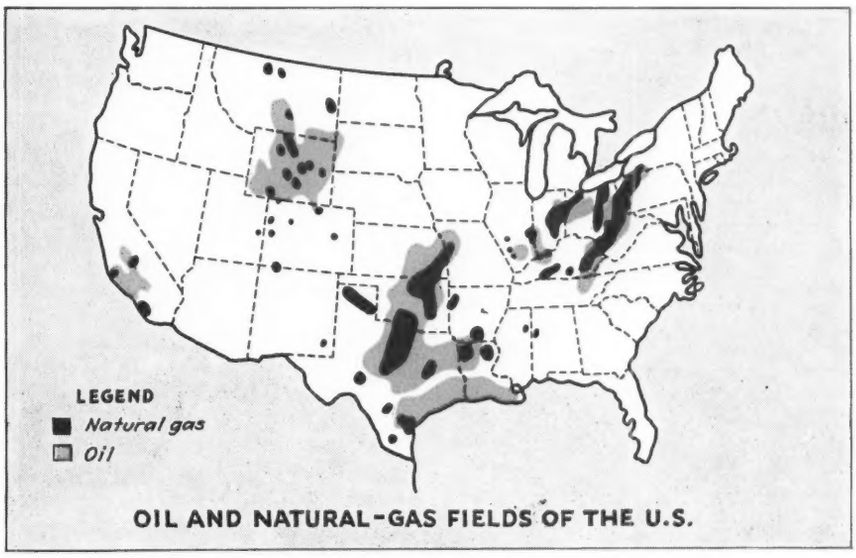
Fuel Gases

Only natural gas has any commercial importance as a fuel for steam generation. Manufactured gases run too high in cost for this purpose. In most cases, byproduct gases run low in heating value and are produced in quantities inadequate for widespread distribution.

Natural gas and oil have a common ancestry and as the map shows, frequently occur together. Rapid strides in construction of pipelines brings natural gas to consuming centers far-removed from the fields; at present, promoters plan a line from Texas to the Philadelphia-New York area.

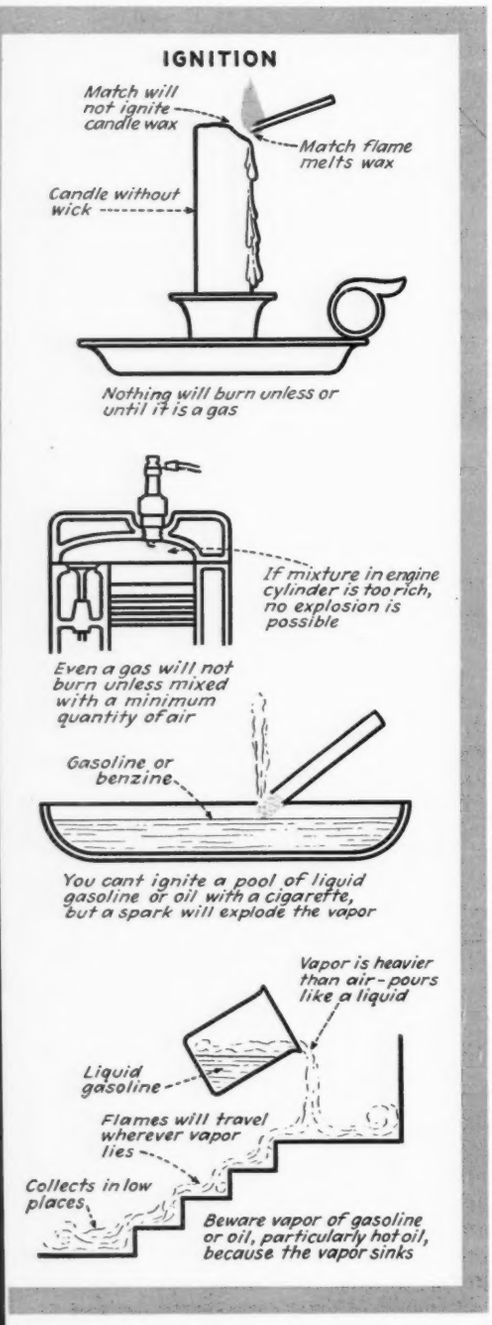
Natural gas is colorless and odorless, burns with a slightly luminous flame, and is highly explosive when mixed with air. It usually contains methane (CH_4) and ethane (C_2H_6), both hydrocarbon gases. Small amounts of carbon dioxide and nitrogen complete the typical analysis. The heating value averages about 1000 Btu per cu ft (20,000 Btu per lb) but may run as high as 2000. Because in its natural state this gas constitutes a nearly ideal fuel, it is necessary to know little more of its characteristics than the ultimate analysis and the heating value. A modification of the well-known Orsat apparatus provides a simple and reliable means of carrying out an ultimate analysis. Heating value is usually measured by the Junkers calorimeter, but may be calculated from the ultimate analysis. In some cases natural gas is sold by the *therm* (1,000,000 Btu) instead of by the cu ft.

Of the byproduct gases, butane and propane find increasing use in engines. Refinery gas, the next richest, makes a good boiler fuel in refinery power plants. Blast-furnace gas, coke-oven gas and producer gas usually contain solid matter which is removed by cleaning. However, blast-furnace gas has been used directly in a boiler furnace with little or no cleaning, and has proved entirely satisfactory. The low heat content of these gases, particularly blast-furnace and producer, makes it uneconomical to distribute them at any distance from the source.



OIL AND NATURAL-GAS FIELDS OF THE U.S.

How Fuels BURN


IGNITION
Match will not ignite candle wax
Match flame melts wax
Candle without wick
Nothing will burn unless or until it is a gas
If mixture in engine cylinder is too rich, no explosion is possible
Even a gas will not burn unless mixed with a minimum quantity of air
Gasoline or benzine
You cant ignite a pool of liquid gasoline or oil with a cigarette, but a spark will explode the vapor
Vapor is heavier than air - pours like a liquid
Liquid gasoline
Flames will travel wherever vapor lies
Collects in low places
Beware vapor of gasoline or oil, particularly hot oil, because the vapor sinks

Carbon and hydrogen are the constituents of a fuel that burn, or we can say that oxygen burns. Actually the first two combine with the last; the resulting chemical action gives off heat, the important thing we are after

MOST of our knowledge of heat, burning, fire and smoke comes by direct experimental trial and error. We accummulate many misconceptions because the experience comes to us at an early age. Many years later, ideas partly or totally wrong remain fixed in our minds along with sound conceptions more recently accummulated. Heat does not rise; hot air rises. Gasoline does not explode; the vapor it gives off so readily will burn rapidly if mixed with enough air. Flame is not always yellow; some flames are blue, some colorless. Smoke is composed of solid particles, but they were once a gas.

Because an *understanding* of what happens in and near a fire is essential to diagnosing trouble with it, and because getting down to fundamentals at the beginning saves explanations later, several simple facts are here set down as foundation material. When a clear conception of what things will burn and how they can be ignited is kept in mind, CO in a flue-gas analysis and smoky oil flames are easier to correct.

Nothing will burn unless or until it is a gas. The wax of a candle cannot be ignited unless there is a wick. The wick, when heated by the flame of a match, draws up a little melted wax by capillarity until a little can be vaporized and ignited. A pool of gasoline cannot be lighted from a cigarette because the smouldering tobacco uses up all the oxygen nearby and cannot raise the temperature of either liquid or vapor to the ignition point. Fuels that liquefy on heating usually melt at temperatures below their flash point. Solid fuels must be swept by fast moving air to remove the gas formed in burning and expose an added layer of incandescent atoms to the grasping arms of an oxygen molecule.

Even a gas will not bu.n until it is mixed with a minimum amount of air. A flooded carburetor has puzzled many an irate motorist. Too much fuel for the air is as unburnable as too much air for the fuel. All gases have a range of mixtures with air within which combustion is possible. Rich mixtures (much fuel with little air) burn with different amounts of heat and different chemical reactions from lean mixtures.

Effect of Temperature

Temperature affects the speed of burning. Every element of fuel has a temperature range below which the rate of burning in air is so slow as to be unnoticed and above which combustion is violent and self-sustaining. Gases have a "flash-point" temperature. If they are heated above their flash point with sufficient air, combustion spreads from molecule to molecule very rapidly. Liquids are said to have a flash point, but a more accurate description would be that their vapors flash into flame at that temperature.

Higher temperatures at the point of combustion produce more radiant energy. Reflected back on cool fuel, greater radiation causes more rapid ignition, increases rate of flame travel.

Burning takes time. Usual combustion reactions are so fast that the time interval seems instantaneous. It is easy to see that a 12-in. oak log will keep the fireplace warm for a long time but it is not always so clear that an 0.002-in. particle of pulverized coal will travel several feet between the time it

is ignited and complete combustion.

Carbon and hydrogen are the only elementary fuels. All our normal fuel supply originally came from sunshine, carbon dioxide and water, and cost no more than the energy of falling water derived from the same source. When the fuel is burned, it reverts to the original natural products and ash, which also returns to the soil from whence it came. Sulphur and traces of other elements do burn and give off heat, but common practice considers these reactions as negligible and their constituents as impurities. The chemists, too, can produce some interesting types of combustion with entirely different effects from those normally experienced in steam boilers, for example burning aluminum with chemically available oxygen to weld steel rails.

Oxygen from the air is the only elementary burning agent. It can also be said that oxygen is the only commercial fuel since it is necessary to every heat-producing reaction. Air can burn in gas in the same way gas burns in air.

A Chemical Reaction

Combustion is a chemical reaction, but most of the problems associated with burning fuels are mechanical. The actual combination of the elementary carbon and hydrogen with oxygen will proceed rapidly and completely if surrounding conditions are favorable. These conditions can be very simply stated: (1) correct proportions of carbon and hydrogen must be brought into close mixture with a corresponding amount of oxygen, (2) the temperature must be brought up to the ignition point and remain there a sufficient time for all the fuel and oxygen to combine. Carrying out these requirements becomes a varied mechanical problem.

In general, the smaller the particles of liquid or solid fuels, the more intimately they can be mixed with oxygen and the more rapid the chemical reaction. This leads to atomizing liquids and pulverizing solid fuels. Gas fuels are already capable of mixing with air and mechanical problems are reduced to providing the correct proportion.

Burning is most easily understood by starting with the combustion of gas. Since all other fuels burn as gas, (or as if they were gas) the fundamentals are similar.

The old-fashioned "fishtail" burner primarily produces light, incidently also some heat. Ordinary illuminating gas of widely varying composition is forced through a slotted opening into a flat, thin stream. The dark area near the burner tip is cold gas in the process of picking up and mixing slightly with air. Suddenly the mixture reaches correct proportion and starts to burn rapidly only a few hundredths of an inch from relatively cold, too-rich mixture.

This rapid heating "cracks" the gas chemically and sets free carbon particles from the molecules that were previously chemical compounds. The particles of carbon glow to incandescence and make the flame visible. The temperature of the visible part of the flame is nearly constant from bottom to top. Each carbon particle is surrounded by a microscopic envelope of CO_2 which is gradually swept away until the particle is completely burned at the tip of the flame.

Combustion is quite complete, with very little CO. The carbon particles can be chilled and their burning stopped by any cold object put in the flame. The deposit of lampblack or "soot" is identical with similar deposits sometimes found on the tubes of steam boilers.

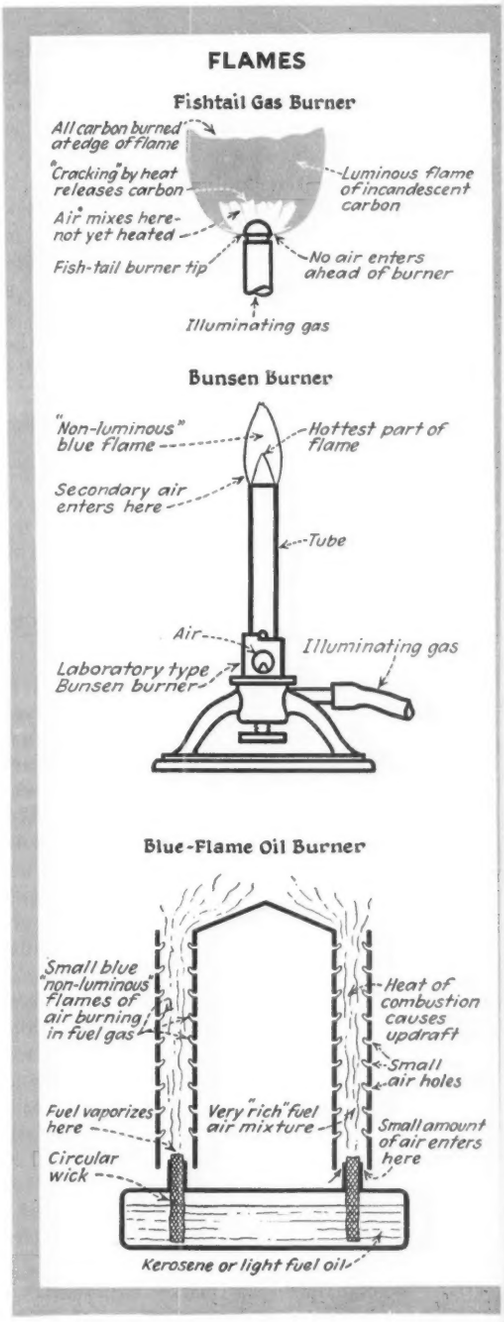
Mixing Gas and Air

When gas is burned to obtain heat, mixing the gas with air before it approaches the flame accomplishes a quite different type of flame. The simple example is a laboratory-type "Bunsen" burner, a small jet at the base of a mixing tube. The flame at the top of the tube then becomes blue and nearly colorless because no particles of carbon are produced.

As the mixture of cold gas and air is heated, more slowly than in the fish-tail burner, some oxygen enters the "hydrocarbon" molecules of the gas and the molecule is "hydroxylated" instead of "cracked". Thus a difference in the point of mixing and in the rate of applying heat produces an entirely different flame that will not deposit soot on a cold surface. The flame passes as "non-luminous" even though quite visible and of a generally bluish color.

The same sort of blue flame can be produced from liquid fuel in a range burner or a "kerosene stove". After a preliminary warming-up period, gas vaporized from the wick by radiation of heat from the flame above, rises between two perforated plates by ordinary chimney action. The mixture is very rich in oil vapor, too rich to burn. Air, however, drawn in the small perforations by the draft created from the hot gas above, forms small flames of air burning in oil vapor exactly opposite to the usual conception of flame. Each perforation forms an individual flame until oil-vapor is consumed.

No attempt is made in power boilers to burn low-grade fuel oils with this type of non-luminous flame because heavy fuel oils "crack" much too easily under the influence of very hot furnaces. Such furnaces must provide for sufficient flame travel to prevent soot deposit on relatively cold walls.



FUEL BEDS in Action

Proper understanding of how the many different types of mechanical stokers work begins with a study of what the stoker is trying to accomplish at each stage in the combustion process, what these processes are, and what effect coal properties have on the problem of getting air to coal

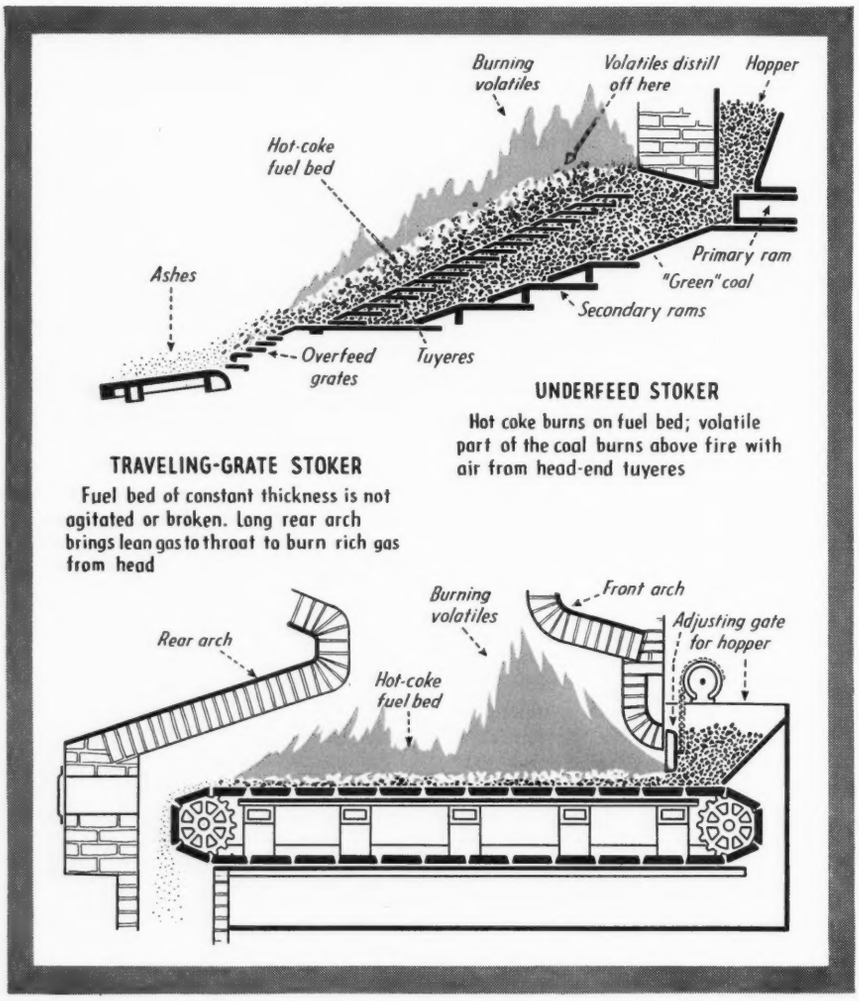
COAL IS STILL the principal fuel for steam and power generation. A large part of "steam" coal is now, and will continue to be, burned on grates.

Present regulation of coal prices by law may not increase the incentive to try lower grade coals in a given installation, but any change in the rules governing natural supplies is apt to require reconsideration of whether or not the best coal for the price is being burned on a given stoker. Selection among several coals can be made on the basis of "steam tests", where the fuel on trial is actually burned for a sufficient period to determine boiler performance, but such tests often do not develop the full possibilities of the new coal because of unfamiliarity with its characteristics on the part of the operator.

Mechanical Stokers

An understanding of the behavior of coal on a fuel bed during its change from "green" coal to ash and flue gas helps any operator make the necesary adjustments on his own stoker to take advantage of coal characteristics. The process of burning is simple, and fundamentally chemical. Stokers on the other hand, are more or less complicated, and their problems are entirely mechanical. Their job is to hold the fuel bed in position while air is brought in contact with the combustible elements long enough to get out all the heat units with the least practical excess air, without smoke, and with a minimum combustible left in the ash.

There are four distinct stages in burning coal on any grate: (1) coal is pushed, dropped, or thrown into a region of high temperature within the furnace, (2) a part—zero to 40% by weight—of the coal is distilled off as combustible gas (mostly hydrocarbons and CO) and burned *above* the fuel bed, (3) remaining solid carbon or coke is kept red hot and swept vigorously by air until completely burned, and (4) remaining ash is removed from the furnace zone.


Burning volatiles
Volatiles distill off here
Hopper
Hot-coke fuel bed
Primary ram
"Green" coal
Secondary rams
Ashes
Overfeed grates
Tuyeres
UNDERFEED STOKER
Hot coke burns on fuel bed; volatile part of the coal burns above fire with air from head-end tuyeres
TRAVELING-GRATE STOKER
Fuel bed of constant thickness is not agitated or broken. Long rear arch brings lean gas to throat to burn rich gas from head
Burning volatiles
Front arch
Adjusting gate for hopper
Rear arch
Hot-coke fuel bed

Important characteristics of coal are ash content and softening temperature, volatile content, caking and coking qualities. Ash-softening temperature and caking qualities not only vary among coals of different seams in the same locality but may be appreciably different under varied conditions of burning. Caking (or coking) and clinkering, more than any other factors, determine the type of fuel bed (stoker) best suited to a given coal, or vice versa.

Classifying stokers by the type of fuel bed rather than operating mechanism, the four types are: (1) underfeed, (2) traveling-grate, (3) overfeed and (4) spreader. Manufacturers have been ingenious in developing mechanical details and modifications aimed at improvement or elimination of specific troubles with certain coals, but these four types of fuel bed are fundamental.

The fuel bed of an underfeed stoker can be quite thick at the head, usually tapers off to extreme thinness at the tail. Coal enters, in multiple-retort designs, between rows of tuyere plates, and generally below both the active fire zone and air-admission zone. Green coal is thus heated slowly over a considerable portion of the fuel bed and air from the head tuyeres mixes with and burns the volatiles. Secondary rams, or pushers, move the entire mass of the fuel bed down the sloping tuyere rows and onto some form of overfeed extension grates where the fuel is finally reduced to ash. Secondary rams not only move the fuel bed but gently break up coke formations.

Coal of any usual ash content can be fired efficiently on underfeed stokers, but low fusion temperature of ash begets clinkering. Water cooling of tuyere rows helps avoid clinkers. Ingenious moving extension grates improve efficiency at high rates of combustion. Non-coking coals can be burned but the underfeed type is standard for high-grade Eastern bituminous coals of the coking type. Good performance is assured at 30-40 lb of coal per hr per sq ft of projected grate area on Eastern coals but high burning rates up to 100 lb have been achieved.

Mixtures of anthracite fines and bituminous coal have been successfully fired on underfeed stokers. Overfire jets of high-velocity air have decreased tendency to smoke at extremely high fuel-burning rates; no additional air is used, as part of the normal air supply is diverted for this purpose. Oil firing as supplementary fuel is also practicable over fuel beds without disturbing the efficient operation of the stoker.

Traveling Grates

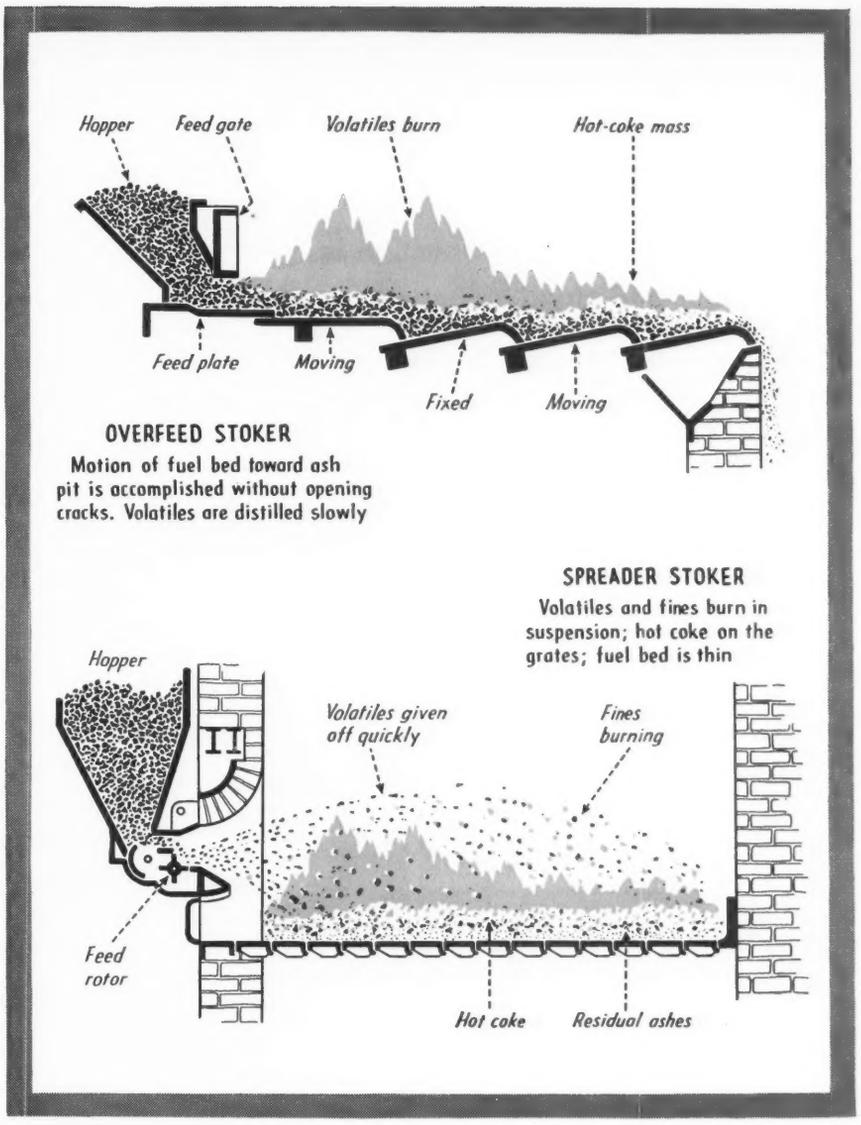
Traveling-grate stokers, either of chain-grate or bar-grate construction, do not agitate or disturb the fuel bed. Consequently, they are best adapted to free burning non-coking bituminous coals, coke breeze, anthracite and lignite. They burn high-ash coals well, but special designs are required if ash content is so low as to form insufficient protection for the grates from the heat of the fire.

The length of time the fuel burns varies with the length of grate and the speed of travel. Fuel-bed thickness is adjusted by an entrance gate. Ignition is aided by refractory arches which also serve to narrow the passage through which unburned volatiles and excess air must pass. The latter effect aids burning of combustible gases and is particularly important in the case of high-volatile coals if high efficiency is to be attained. Many varied arches and settings are used to suit boiler designs and coal characteristics.

Overfeed stokers of the inclined-grate type feed coal onto a hearth or dead plate where volatiles are distilled off. An ignition arch is sometimes provided and overfire air nozzles are common. The grate surface, sliding bars or rocker plates, moves the fuel bed gradually down to the ash pit.

A wide range of coals can be burned on overfeed types of fuel bed but best performance is obtained from relatively small size units operating at moderate coal-burning rates.

Spreader stokers, gaining favor both in new installations and in modernization programs to replace hand firing, most nearly resemble hand firing in the



character of fuel bed produced. Coal is fed by a relatively high speed rotor (or pneumatically) into the furnace at a distance of a foot or more above the flat grate surface. Sufficient impulse is imparted to carry the heavier particles of coal the full length of the grate, lighter ones part way. The fines burn in suspension; medium-size particles distill off most of their volatile content and fall to the grate as hot coke or carbon; very large pieces (preferably not over 1¼-in.) give up at least part of their volatile before dropping on the hot fuel bed of the spreader stoker.

Fuel bed burning for spreader stokers is restricted to coke or carbon and can consequently be maintained uniformly very thin. Most of the combustible is consumed above the grate where air-fuel mixture can be maintained close to most desirable ratio. Spreader stokers have little tendency to smoke, but a considerable proportion of the ash of the fines is carried through the boiler into the breeching.

Several other mechanical combinations of coal-feed and grate motions are utilized to provide refinements of these four fuel-bed arrangements, such as the part overfeed and part traveling-grate design. They differ in the means of maintaining the fuel bed but the principles of combustion are the same.

Efficiency by Air Control

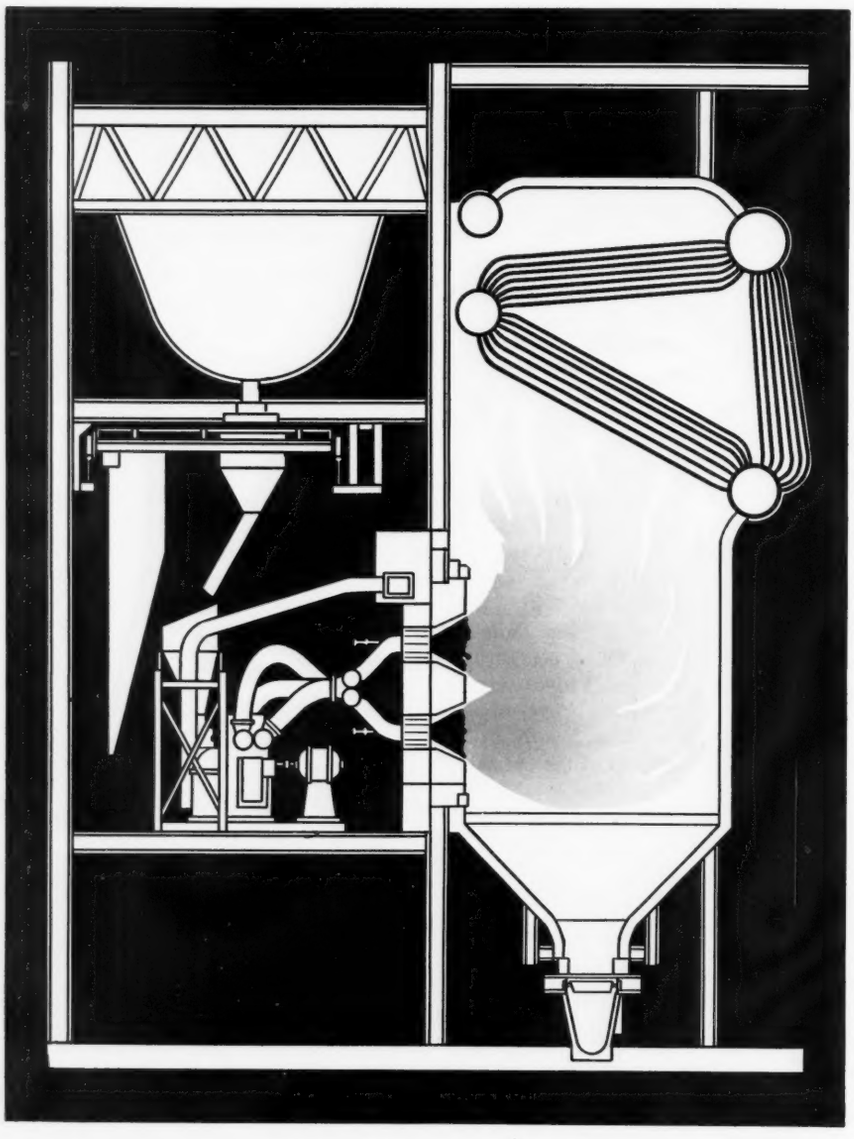
In maintaining all fuel beds the following principles should be kept in mind: (1) The amount of fuel burned and the heat output of the boiler are controlled by varying the *air* supply as practically all the oxygen in combustion air is consumed in passing through the first few inches of hot carbon. (2) Some air must be supplied over the grate to burn combustible gases quickly. (3) Increased turbulence of overfire air improves mixing with combustible gases and improves their burning within restricted furnace volumes. (4) Efficiency depends on maintaining excess air at a minimum (highest CO_2) consistent with complete combustion of volatiles.

Burner Firing

With pulverized coal, combustion is speeded by reducing particle size and aided by better control of fuel-air mixture. With oil and gas, secret is intimate mixing of fuel and air

PULVERIZING COAL to the fineness of flour yields a fuel that will flow in pipes like a liquid and burn in a furnace much like a gas. An 0.002-in. diameter coal particle goes through the same burning process as gas in a fishtail burner or a particle of oil from an atomizing nozzle.

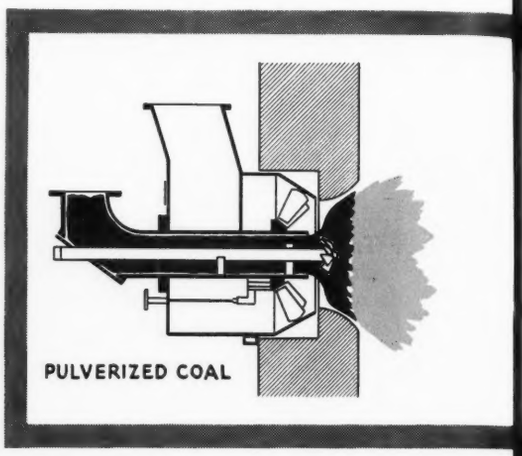
As in a stoker fuel bed, each particle of coal gives up its volatile content within a fraction of a second after the radiant heat of the furnace starts to raise the temperature. Each particle burns separately. Enough air (primary air) is introduced at the burner, intimately mixed with the stream of coal particles, to burn the gas resulting from the separate distillation of each of the stream of particles. The volatiles, mostly hydrocarbons, ignite more easily than the carbon remaining in the particle and heat the latter to incandescence.



Secondary air, introduced around the burner opening in a direction opposing the coal-stream flow, sweeps past the hot carbon particles and gradually burns with them in a flame several feet in length.

Primary air not only serves as a carrier for the coal particles from the pulverizing mill to the burner, but also enters the furnace as part of the coal stream. Thus volatiles burn quickly and without smoke. Secondary air, enough to make up the remainder required for complete combustion, must pass the residual carbon particles at sufficient velocity to sweep away the envelope of CO_2 that surrounds each particle.

High-volatile coals require more primary air than low-volatile coals. A rough and ready rule is that the percentage of primary air should equal the percentage volatile in the coal. High-volatile coals ignite more easily and burn more quickly than low-volatile fuel because a greater part of the heat content is given up by burning gas. Anthracite and low-volatile coals are difficult to ignite (require a rich coal-air mixture at the burner tip and relatively long flame travel). Furnace designs for anthracite include a refractory arch. Finer pulverization aids the speed of burning for such coals.



Most of the early experience with burning coal in pulverized form was obtained from large central-station boilers. Advantages in control of fuel and air flow, speed of burning, and efficient combustion of slack coals offer greatest incentive in large-size units.

Furnaces for pulverized-fuel firing are completely or nearly completely water cooled. High temperatures resulting from radiation of incandescent fuel particles tend to destroy refractory rapidly; heat-absorbing surface built into the furnace walls reduces the amount of convection surface necessary in the boiler proper.

Burners are of many types. Large

quantities of coal per burner are usually fired between the tubes of the water wall in multiple-opening burners. Turbulence is created by directing the secondary air to carry the coal stream downward or, by firing from the four corners of a vertically disposed furnace, in a swirl occupying the entire furnace volume. Smaller burners impart a rotation of the primary coal-air mixture in one direction and the secondary air oppositely.

In any case, it is the function of the burner to mix the primary and secondary flows with a maximum of turbulence to insure relative motion between individual coal particles and fresh oxygen, after the volatile part has been consumed, in order to burn the carbon completely. Volatile gas burns with a hot luminous flame; carbon particles may still be giving up useful heat a considerable distance after the flame apparently ends.

Furnace and burner arrangement depend greatly on the properties of ash in the coal. In general, high fusion temperature of ash indicates the use of a dry-bottom furnace, low-fusion-ash coals, especially in large boilers, are fired in slag-tap furnaces.

Ash formed under good combustion conditions contains iron in a highly oxidized form and has a higher firing-temperature range than indicated by laboratory tests. Fineness of pulverization and good combustion reduce the carbon content of the ash and so tend toward higher oxidation of the iron, thus keeping the ash from forming slag on water walls and tubes in the dry-bottom furnace.

Slag-tap furnaces, developed about 1926, remove a part of the ash from the combustion zone by directing the burner flame generally downward over a pool of molten slag. These furnaces are suitable for high heat releases and tend to remove the low-fusion temperature elements of the ash so that less slagging occurs on the walls and boiler tubes proper. Slag pools must be kept hot enough to remain molten so that the slag flows continuously over a water-cooled weir or ring into a quenching pit where it is broken up by water streams.

Pulverized-fuel firing offers most advantage in large-size units where its over-all cost compares favorably with stoker firing and the inherent operating efficiencies can be realized fully. Units from 30,000 to 250,000 lb per hr steaming capacity require economic consideration of stokers with pulverized coal to determine what local factors justify the one over the other. Smaller units, below 30,000 lb per hr, have been developed and operate well, but more simple stoker installations will usually be found preferable when all factors are considered.

One of the advantages often advanced for pulverized-coal firing is the ability to obtain the full benefits of air preheat. While stokers now are operating satisfactorily with preheated air temperatures around 500 F, good practice usually restricts this value to about 350 F. No actual limit can be placed on the temperatures used with pulverized-coal, although 550 F is usual. Preheated air, occupying considerably more volume per lb than cold air, produces a somewhat longer flame, so that a burning carbon particle can find enough oxygen to become completely consumed.

Preparation of coal for pulverized firing requires (1) a measuring device for supplying coal at a uniform controlled rate to the mill, (2) pulverizing in a hammer, roller or ball mill to the most economical degree of fineness, (3) supply of warm dry air to the mill to pick up and transport the coal, (4) piping to convey the coal-air mixture to the burner.

Practically all present-day pulverized-fuel installations are "unit-mill" arrangements in which coal is fired immediately after pulverizing; no pulverized-coal storage is provided. The unit system is not only simpler, involving less auxiliary equipment, but avoids hazard in that the quantity of pulverized coal never exceeds that contained in the mill and the short length of piping to the burner.

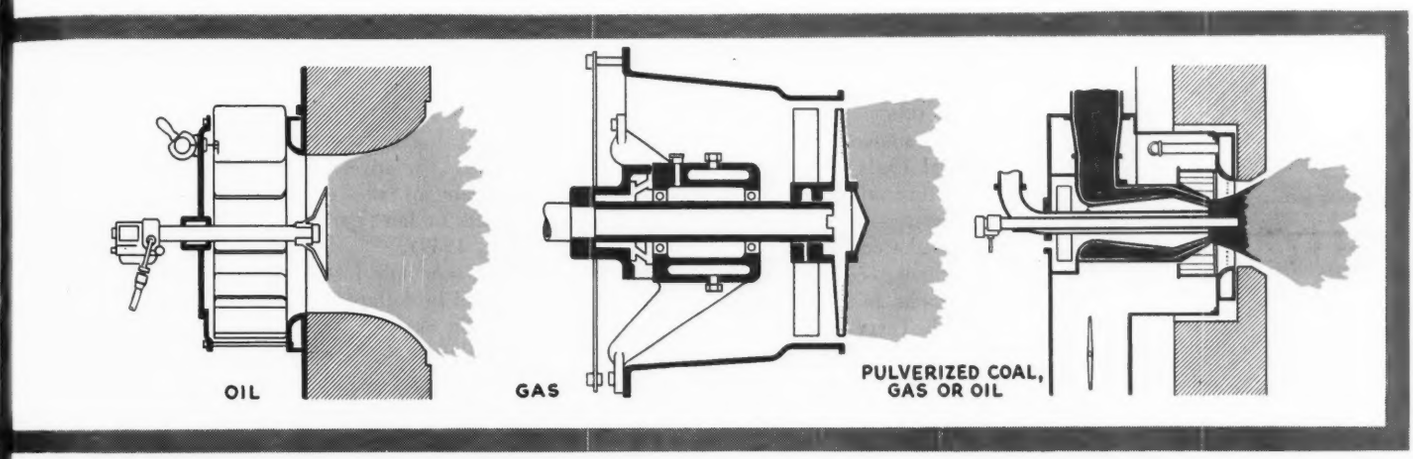
Such drying of coal as required is usually done within the pulverizer. Preheated air is tempered by cold air to 160–200 F and drawn or forced into the mill. Wet coals require somewhat higher temperatures. Air thus drawn through the mill carries the coal to the burner and is used for combustion.

Oil and Gas Burning

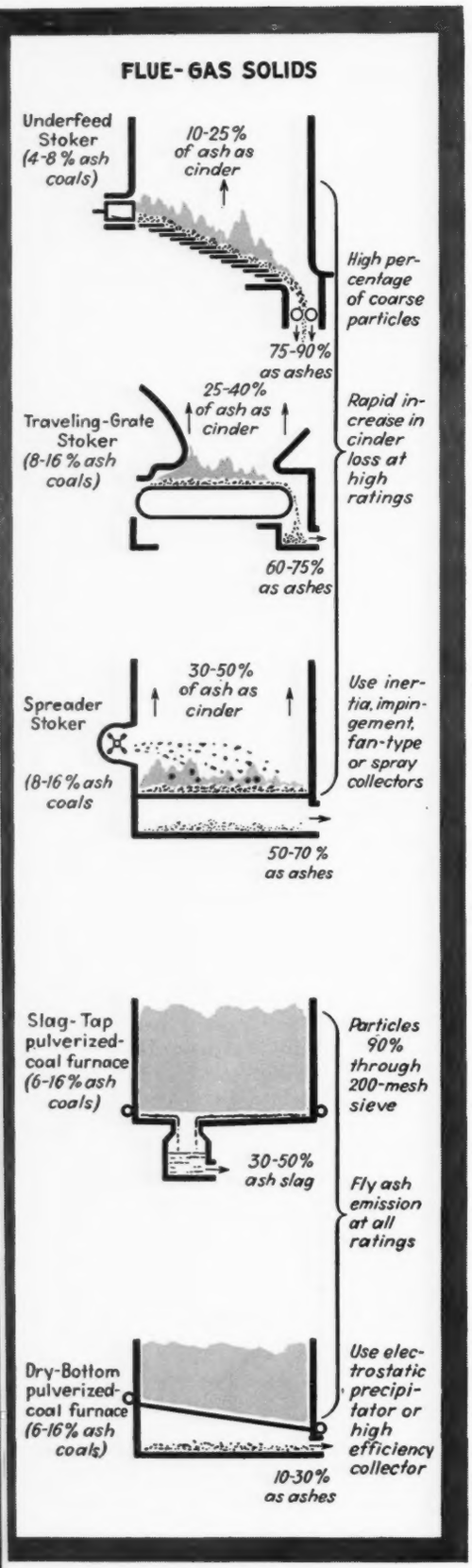
Liquid and gas fuels require no elaborate equipment or preparation for burning. Fuel oil of high viscosity must be heated to 180 F or higher to provide sufficient fluidity for atomization at the burner.

A good flame and complete combustion from an oil burner depend on thorough atomization of the fuel at the burner whether by forcing mechanically the oil through a nozzle under pressure or by using auxiliary steam. Enough air must, of course, be blown into the furnace through burner registers to mix quickly with the drops of fuel. If the amount of air is insufficient, if mixing is not quickly obtained, or if atomization is not fine enough to secure rapid ignition and burning, the oil will crack to give off soot and tarry vapors. Steam-atomizing types require about 1% of the boiler output for steam supply to the burner.

Burning small quantities of gas requires only a simple venturi tube to premix air and gas before they reach the heat of the furnace. Many commercial burners, therefore, are subdivided into small units each firing through its own mixing tube. Others of larger diameter employ an impeller to ensure complete mixing of air and gas. If combustion conditions are correct, the furnace will be clear and without visible flame.



Smoke, Flyash and Cinder


FLUE-GAS SOLIDS
Underfeed Stoker (4-8% ash coals)
10-25% of ash as cinder
High percentage of coarse particles
75-90% as ashes
Traveling-Grate Stoker (8-16% ash coals)
25-40% of ash as cinder
Rapid increase in cinder loss at high ratings
60-75% as ashes
Spreader Stoker
(8-16% ash coals
30-50% of ash as cinder
Use inertia, impingement, fan-type or spray collectors
50-70% as ashes
Slag-Tap pulverized-coal furnace (6-16% ash coals)
Particles 90% through 200-mesh sieve
30-50% ash slag
Fly ash emission at all ratings
Dry-Bottom pulverized-coal furnace (6-16% ash coals)
Use electrostatic precipitator or high efficiency collector
10-30% as ashes

The way to cure smoke is not to make it; the remedy for solids-discharge nuisance is separating ash particles from flue gas. Here are basic principles and how to apply them

CONSTITUENTS that tend to form smoke are as much a part of natural coals as the elements that have heating value. The particles of ash that form flyash and cinder were also built into the coal and cannot be eliminated.

Smoke comes from tar and hydrocarbons in the volatile portion of the coal. Tarry compounds and hydrocarbons are gasified by the heat of the furnace and unless mixed with air and burned quickly, decompose to form soot particles. These represent nuisance from a smoky stack and loss of efficiency because part of the combustible is not burned. Smoke is composed of particles mostly sub-microscopic; they probably fall to earth only when they collect moisture and help form fog and rain.

Why Smoke Forms

Physical causes of smoke are: (1) insufficient excess air or overfire air, (2) too vigorous agitation of the fuel bed, (3) too rapid distillation of volatiles, (4) too small or too cold a furnace.

Cinder and flyash have come to be taken as only those particles that were part of the solid coal, remained solid throughout the combustion process and have been swept up through the boiler by high-velocity flue gas. If the coal contains fine particles (below ¼ in.) and high air velocities through fuel beds or in pulverized-coal furnaces are necessary for high ratings and efficient combustion, then cinder or flyash will be carried up with the flue gas. Whether the discharge is a nuisance or not depends entirely on the quantity of discharge, the size range of the particles and the character of the surrounding neighborhood.

Stoker cinder, somewhat finer than flyash but containing 10-15% of through-200-mesh particles, can be kept out of the nuisance class by any of several relatively low-cost cinder catchers of the centrifugal, cyclone, washer or fan types (POWER, July, August, 1939).

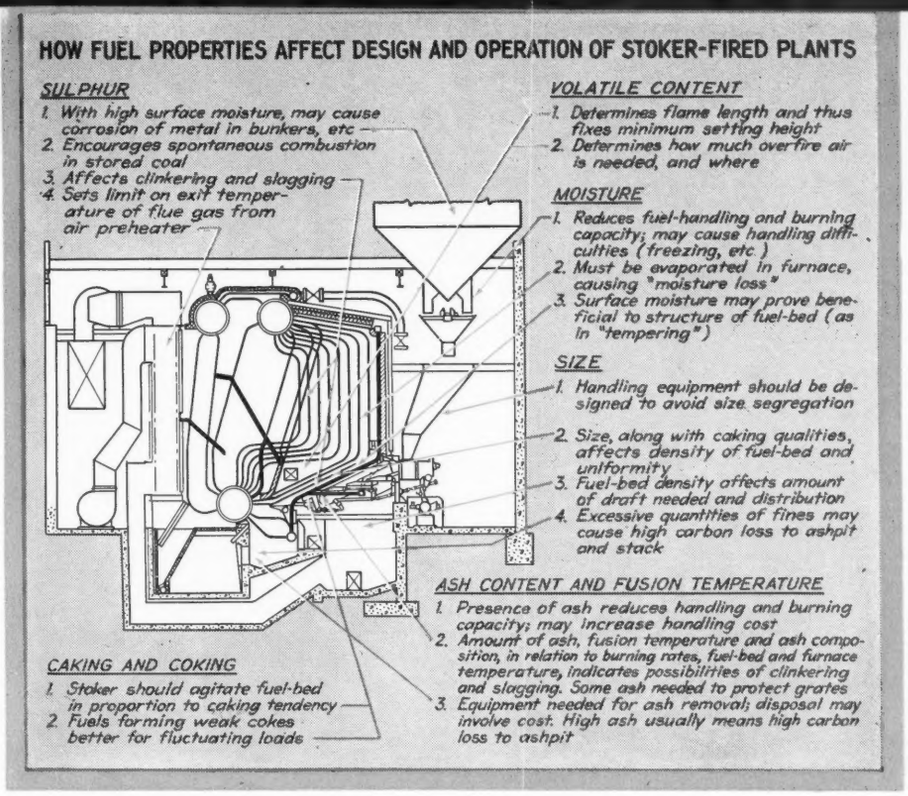
No economic justification can be calculated in dollars as a return on investment in cinder catchers as they do not contribute to combustion efficiency or anything else except "to keep the neighbors happy". However, because the cost is reasonable, small in proportion to the total boiler-plant investment, and because the nuisance is real in settled communities, there is a definite trend toward installing cinder-removal equipment.

Flue-Gas Solids

Underfeed stokers usually are favored with low-ash coals. Only when operated at high ratings does more than 1% of the total coal (perhaps 5-10% of the ash content) go up into the boiler. Because the cinder contains a large proportion of coarse material, much is deposited in boiler passes and flues.

Traveling-grate and spreader stokers usually burn high-ash coals and considerable quantities of cinder are apparent even at moderate coal-burning rates. Simple, low-cost cinder-catching devices reduce the nuisance to an acceptable stack-discharge condition for most localities.

Original dry-bottom pulverized-coal boilers collected only 10-20% of flyash below the furnace; the remainder inevitably went up through the boiler unit, and, because of its fineness, out the stack. Larger furnaces and slag-tap designs can account for up to 50% of the flyash. Stack discharge can be kept low only by electrostatic precipitators or high-efficiency, inertia-type dust collectors.


HOW FUEL PROPERTIES AFFECT DESIGN AND OPERATION OF STOKER-FIRED PLANTS
SULPHUR
1. With high surface moisture, may cause corrosion of metal in bunkers, etc
2. Encourages spontaneous combustion in stored coal
3. Affects clinkering and slagging
4. Sets limit on exit temperature of flue gas from air preheater
VOLATILE CONTENT
1. Determines flame length and thus fixes minimum setting height
2. Determines how much overfire air is needed, and where
MOISTURE
1. Reduces fuel-handling and burning capacity; may cause handling difficulties (freezing, etc.)
2. Must be evaporated in furnace, causing "moisture loss"
3. Surface moisture may prove beneficial to structure of fuel-bed (as in "tempering")
SIZE
1. Handling equipment should be designed to avoid size segregation
2. Size, along with caking qualities, affects density of fuel-bed and uniformity
3. Fuel-bed density affects amount of draft needed and distribution
4. Excessive quantities of fines may cause high carbon loss to ashpit and stack
ASH CONTENT AND FUSION TEMPERATURE
1. Presence of ash reduces handling and burning capacity; may increase handling cost
2. Amount of ash, fusion temperature and ash composition, in relation to burning rates, fuel-bed and furnace temperature, indicates possibilities of clinkering and slagging. Some ash needed to protect grates
3. Equipment needed for ash removal; disposal may involve cost. High ash usually means high carbon loss to ashpit
CAKING AND COKING
1. Stoker should agitate fuel-bed in proportion to caking tendency
2. Fuels forming weak cokes better for fluctuating loads

Which Fuel For Your Plant?

Designing a plant without first making a careful analysis of the fuel situation is like buying a railroad ticket without first deciding where you are going—it can be done but there isn't much sense to it. Here is an outline of the factors involved in making a thorough-going fuel survey

A FUEL is a package of energy (Btu's) plus other qualities, good and bad, which affect the way it behaves in use and so affect the equipment needed to burn or handle it. Because the package can't be taken apart, selecting fuels cannot be reduced to simple terms. The job of picking your fuel breaks down into two phases, depending on whether a proposed plant or an existing plant is involved.

In the first case, the problem is to get a combination of fuel and equipment that will meet all the operating requirements, both present and future, with the lowest over-all cost. In the second case, the problem involves analyzing equipment characteristics to determine which fuels can be burned satisfactorily and then finding which of these will prove most economical. Let's look at the first problem more closely.

A thorough-going fuel survey should precede everything but the decision to build a steam plant, since choice of fuel affects practically every item in the boiler house. The purpose of such a survey is threefold: (1) to find out what fuels are available in a given area, (2) to establish the relative value of these fuels, and (3) to attempt to predict, or at least allow for, changes in relative value in future years. It would be wrong to say this is a simple job, except where only a few fuels are available, but there is no part of the design that will pay bigger dividends over the life of the plant. In many cases, it pays to bring in an expert fuel consultant to make the survey.

Where gaseous and liquid fuels are available, the matter of type and grade plays little part and the survey is relatively simple. Where coal is involved, the story is likely to be different; here is where the job is usually skimped. In many areas, a wide range of kinds and sizes of coal is available and, in the past, the engineer rarely knew about more than a small fraction of them. To some extent the operation of the Bituminous Coal Act of 1937 (the Guffey act) helps remedy this situation; let's see why.

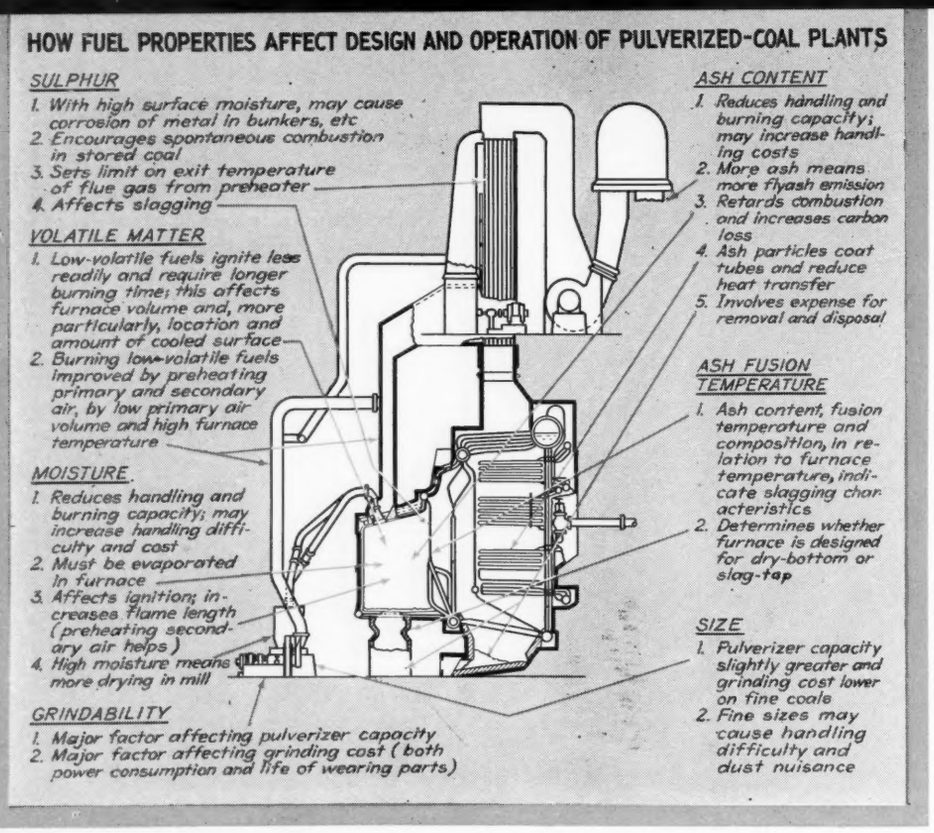
Under the Bituminous Coal Act, the nation is divided into 23 producing districts and more than 200 market areas (see maps, pages 72, 75). In each market area, there is a minimum price for each kind and size of coal shipped into that area; coal may not be sold at less than the minimum price for its size and grade. A schedule of the prices is on file at the Bituminous Coal Division, Dept of the Interior, Washington. These prices, which were arrived at after lengthy conferences and public hearings, take into account such factors as cost of production, freight, and competitive conditions, as well as the various useful or objectionable properties of the particular coal involved.

Guffey Act Effects

From the buyer's point of view, the practical effects of the Act are: (1) a slight increase in the *average* price of coal (some coals are cheaper than before price-fixing, others are more expensive), (2) a slight decrease in the price spread between premium coals and "low-grade" coals, and (3) stabilization of the market and elimination of "spot" bargains. The Act does not in any way equalize values or eliminate the possibility of savings resulting from careful selection of coal. It does eliminate savings from "smart buying," from taking advantage of local or seasonal distress conditions. To this extent it makes coal buying more of a "technical" science and less a "business" art.

Studies leading to setting minimum prices yielded what promise to be valuable byproducts, highly useful in making fuel surveys. For example, the tabulation on page 74 shows what coals were shipped into each market area in 1937. This gives a factual start to any coal study. The first step involves finding the market area in which the proposed plant is to be located, using either the map on page 75 or, for borderline cases, the booklet published by the National Coal Association, Washington, D. C. (Bituminous Coal Railroad Freight Destinations, $1.00.)

For any market area, we can find from the tabulation which producing districts


HOW FUEL PROPERTIES AFFECT DESIGN AND OPERATION OF PULVERIZED-COAL PLANTS
SULPHUR
1. With high surface moisture, may cause corrosion of metal in bunkers, etc
2. Encourages spontaneous combustion in stored coal
3. Sets limit on exit temperature of flue gas from preheater
4. Affects slagging
VOLATILE MATTER
1. Low-volatile fuels ignite less readily and require longer burning time; this affects furnace volume and, more particularly, location and amount of cooled surface
2. Burning low-volatile fuels improved by preheating primary and secondary air, by low primary air volume and high furnace temperature
MOISTURE
1. Reduces handling and burning capacity; may increase handling difficulty and cost
2. Must be evaporated in furnace
3. Affects ignition; increases flame length (preheating secondary air helps)
4. High moisture means more drying in mill
GRINDABILITY
1. Major factor affecting pulverizer capacity
2. Major factor affecting grinding cost (both power consumption and life of wearing parts)
ASH CONTENT
1. Reduces handling and burning capacity; may increase handling costs
2. More ash means more flyash emission
3. Retards combustion and increases carbon loss
4. Ash particles coat tubes and reduce heat transfer
5. Involves expense for removal and disposal
ASH FUSION TEMPERATURE
1. Ash content, fusion temperature and composition, in relation to furnace temperature, indicate slagging characteristics
2. Determines whether furnace is designed for dry-bottom or slag-tap
SIZE
1. Pulverizer capacity slightly greater and grinding cost lower on fine coals
2. Fine sizes may cause handling difficulty and dust nuisance

shipped into that area, and how much. Remember that these figures, while the best available, represent conditions in 1937, and that the operation of the Act has and will change the picture somewhat. As a practical matter, the relative amounts shipped have little bearing on the fuel survey; the major use of the table lies in showing what coals are available in a given market area.

To find the characteristics of coals from a given producing district, consult the typical analyses on page 73. These are based on a complete set of typical and range analyses for each bed and seam, prepared by the Bureau of Mines and the Consumers Counsel, Bituminous Coal Division, from the vast number of analyses introduced at public hearings on the Act and from existing data. In a short time, complete analysis data, maps of producing districts showing mine locations, and complete lists of mines, will be published by the Consumers Counsel, Bituminous Coal Division, Dept. of the Interior. Copies of these "Data Books" will be available at a nominal price.

Set up Fuel List

From these sources it is possible to set up a list of the fuels available to the proposed plant, complete with characteristics and prices. This should be arranged on a cost-per-delivered-Btu basis. If allowance didn't have to be made for differences in the properties of the fuels and, therefore, in the kind and amount of equipment necessary for handling and burning them, this list would give the answer. As it is, it's just a starter toward a more complete study which takes into consideration plant design and cost.

It is obviously impractical to make a complete study for each fuel involved, showing estimated operating costs (including maintenance) and estimated investment. Luckily this is rarely necessary. In most cases it will be possible to estimate operating costs for gas, oil, and the best coal, and to prepare rough investment figures for each kind of plant. Although the kind of coal to be fired makes some difference in plant investment, it is relatively slight compared to differences between oil or gas and coal.

More Accurate Analysis

If the results of this preliminary analysis come out closely enough to be affected by differences in investment required for several types of coal, the comparison can be made on a more accurate basis. As a practical matter, in such cases it might be wiser to decide on coal, since a later change to oil or gas would require only a modest investment. A combination-firing arrangement might represent the best answer.

At this stage, consideration should be given to possible future shifts in the fuel situation. In general, coal prices are stable and change fairly slowly. Large supplies, consistent production costs, regulated freight rates, and now price-fixing all contribute to this stability. On the other hand, oil and gas prices show a much more variable trend, being more limited in supply. A study of past performances of each fuel in the given area will shed some light on the situation. Where the outlook is doubtful, it may pay to add slightly to the investment and provide for combination firing. A few years of burning low-price oil may wipe out the added investment for oil firing and show a handsome profit (see "Hotel New Yorker Goes Back to Coal," POWER, September, 1940).

Assuming that the preliminary analysis shows some form of coal to be the best fuel, what happens next? This depends somewhat on the coals involved, and also on the kind of firing equipment contemplated. A few examples will show how this works out. Assume the plant in question is, for controlling reasons, to be stoker fired. If the comparison lies between a free-burning and a caking coal, the nature of the stoker selected will depend largely on the choice of coal. If the free-burning coal and the necessary unagitated-fuel-bed stoker proves the best combination, such a choice more or less rules out caking coals from later consideration. Where the decision carries this limiting effect, it should be made with extreme care, and assurance as to continuance of the supply and price situation is necessary.

Does Versatility Pay?

The other common situation can be illustrated by considering a large plant, where pulverized firing is contemplated. Here the choice is like to be, not between two setups differing considerably in type, but between setups differing largely in degree. Specifically, such a case is likely to boil down to a comparison between a minimum-investment plant which will burn satisfactorily only the best coals of the lot or a similar but more expensive arrangement capable of handling any coal in the group. This latter layout will probably include greater furnace volume, more pulverizer capacity, drying facilities, etc.

Keeping first cost down weighs heavily with both buyers and manufacturers. At such a time, possible future savings from using cheaper fuels and from greater latitude in fuel buying, are likely to look small. Experience proves this attitude shortsighted in many cases and it seems sound general practice to build as much fuel versatility into a plant as is economically possible.

Even after a wise choice as to fuel and general plant layout is made, the question of fuel must be kept in the forefront at every stage of the actual design. Fuel properties and plant design tie-in at many points, as the diagrams on pages 85 and 86 show. Attention to this angle at the drafting-board stage will prevent some small limitation creeping into the plans which will look big when the time comes to operate the plant and buy fuel for it.

Spending the Fuel Dollar

High steam cost and operating headaches follow "needle-in-the-haystack" fuel buying. Getting the most for your money means knowing first what fuels you can't burn and then selecting the most economical of those you can

FUEL SELECTION responsibility rests squarely on the shoulders of the power engineer. He is the only man, aside from the independent fuel consultant, who understands all the facts needed to spend the fuel dollar wisely. The purchasing agent can help with his knowledge of market conditions and buying procedure, the salesman and fuel-service engineer can supply facts about their fuels, but the power engineer must coordinate these with plant requirements and make the choice.

Because coal is a complex substance with many good and bad properties in addition to the heat energy for which it is bought, coal selection cannot be reduced to a simple formula. What follows is an outline of a sound procedure which can be followed in most plants. Because it involves a minimum of testing and a maximum of "horse-sense," it comes closest to meeting the needs of the small plant.

The right coal for any plant is the one that will carry the load, meet all reasonable operating requirements and produce lowest over-all steam cost. While any coal can be burned in any plant, after a fashion, every practical engineer knows that many plants have design and equipment limitations that bar certain coals, either because they will not carry the load, because reliability will be seriously impaired, or because intolerable operating difficulties will be encountered. Regardless of price, such coals cannot be used.

To eliminate a lot of unorganized trial-and-error testing, the power engineer must examine every part of his plant from coal pile to ashpit and stack, with but one thought in mind, to locate and evaluate every factor affecting coal selection. Even the engineer familiar with his plant will find such a fuel-engineering analysis reveals limitations he wasn't aware of or puts the finger on the exact cause for some limitation vaguely recognized.

Of equal importance, he will find that some limitations thought to exist will disappear on close examination. By removing false restrictions on coal choice, the analysis may actually widen the range of coals suitable for use and so lead to savings from wider latitude in buying. The analysis will also show how much weight to give various fuel properties that affect operation favorably or unfavorably but do not necessarily bar the coal from use.

The check lists on this page and the next give some idea of the questions the power engineer must ask and answer in making a fuel analysis of his plant. Experience and records will furnish some of the answers definitely and easily; others will have to be determined by trial. For example, a low boiler setting causes smoke trouble at high burning rates with high-volatile coals. The engineer knows this but has no records that would indicate the maximum amount of volatile matter that will permit operation at high rates without exceeding the smoke requirements. A few tests with sample shipments of coal will give the answer.

Limiting Factors

Limiting factors on coal use will take various shapes in different plants; in many cases the limitation will occur outside the furnace. For example, inadequate ash-handling equipment may require putting a limit on the ash content of fuels burned. A plant equipped with excessive preheater surface, which produces a low exit-gas temperature, may find it necessary to limit sulphur content of fuels burned to avoid rapid and expensive corrosion of preheater and breeching.

In considering the furnace and firing equipment, it will be found that each factor of the design must be considered in relation to the burning rates encountered and to the nature of the load; that is, whether it is steady or fluctuating. For example, the minimum ash-fusion temperature for clinker-free operation on an underfeed stoker depends largely on combustion rate. Likewise, the nature of the load affects the importance of the caking qualities of coals; a fluctuating load may bar a strongly caking coal from use on a stoker with inadequate agitation of the fuel bed, or from a hand-fired grate.

The engineer must also remember that one property of a coal may modify

Check List of General Plant Conditions Affecting Coal Selection

FUEL AND ASH HANDLING:

- Is coal stored long enough to make weathering important?
- Need to watch spontaneous-combustion tendencies?
- Would wet coal hamper flow and cause freezing?
- Does rough handling bar extremely friable coals?
- Would dust from excessive fines constitute a nuisance?
- Must ash be limited because of inadequate handling?
- What is coal and ash-handling cost per ton, including labor?
- Do segregation difficulties put a premium on sizing?

LOAD CONDITIONS:

- What burning rate results from maximum load? Duration?
- What is lowest load to be carried for any length of time?
- Is load fluctuating or fairly steady?
- Is spare boiler capacity always available?

SMOKE AND DUST EMISSION

- Is smoke emission restricted by law?
- Is there any specific restriction on flyash? If so, what?
- Does the plant have effective dust-collecting equipment?

OPERATION:

- To what extent is combustion controlled automatically?
- Are operators experienced and competent?
- Does plant have adequate metering equipment for tests?

another. Thus presence of excessive fines may aggravate clinkering tendencies, producing trouble with a coal having apparently satisfactory ash-fusion characteristics.

Finally, in making the fuel analysis of his plant, the engineer must distinguish between limitations and preferences. For example, in a plant with barely enough pulverizer capacity, if grindability drops below a definite point, the load can't be carried; coals with lower grindabilities are worthless. However, if pulverizer capacity is ample, the engineer may still prefer high-grindability coals since grinding costs will be somewhat less. The saving in power consumption and in cost of replacing wearing parts will indicate how much can be paid for higher grindability. Some properties of coal have importance only as limits, never as preferences. For example, once the minimum ash-fusion temperature for trouble-free operation has been determined, any increase in fusion temperature has no value.

The completed plant analysis boils down primarily to a set of limitations expressed as far as possible in coal properties that can be measured (ash content, fusion temperature, sulphur content, etc) with properties that still defy exact expression (caking quality, weathering properties) stated as clearly as possible. Armed with this analysis, the power engineer can tackle the list of coals available in his district, eliminating immediately those that fail to meet the minimum requirements.

At this point relative prices enter the picture. The list of coals remaining after the first elimination should be set up on the basis of delivered-cost-per-Btu. This will immediately permit a second elimination, divided into two parts: (1) of the coals meeting all requirements, eliminate all but the best two or three from the delivered cost standpoint, and (2) from the coals exhibiting one or more undesirable qualities, eliminate those where low cost seems insufficient to compensate for undesirable properties.

Note that up to this point the only testing required has been of a simple sort and that even such trials as mentioned for setting the upper limit of volatility are only needed where plant records and observations are lacking on a particular point. Elimination can be carried even further without need for full-fledged evaporation tests. Each of the coals whose cost per Btu is low should be studied to determine how much weight must be given to the undesirable properties which pull its price down. High ash content may make no difference in a plant where ash can be sold; in a plant where removal must be paid for every increase in ash content involves a definite cash outlay. On this basis, other coals can be eliminated, still without testing.

For the small plant without test instruments, this may be enough. What looks like the best value among the remaining coals can be used for a short period. If it behaves satisfactorily and there is no apparent increase in operating troubles or maintenance it can be used with a fair degree of confidence.

If the plant has equipment for evaporation testing, plant trials will help verify the analysis up to this point and further sort out the remaining coals. By avoiding hit-or-miss plant testing, a large number of coals can be given consideration and the necessary careful testing can be given those worthy of it, all without excessive expense.

To be worthwhile, plant tests must be carefully made and the results must be analyzed properly. The errors involved in casual tests will often exceed the differences in coal quality. Every effort must be made to keep load conditions about the same from test to test. Boiler surfaces should be equally clean. Finally, each coal should get equal attention and skill from the operating force. This does not mean each should be fired the same way; it means each should be fired to get best results, allowing for its peculiarities on the given equipment. This, in turn, means that each test should be preceded by a "warm-up" period to give the operating force a chance to get acquainted with the coal and its behavior. During this warm-up and the test itself, everything connected with the coal's performance should be studied and checked against the plant analysis.

If none of the coals display any markedly unsatisfactory operating characteristics, final selection will depend on over-all steam cost indicated for each. This will be made up of fuel cost, as calculated from the evaporation results, and maintenance and labor costs as estimated from observation.

Differences in evaporation results must be taken with a grain of salt since relative coal values are not the only factors affecting evaporation. Operation of other factors can often be determined and allowed for by calculating a boiler heat balance. By knowing what happens to the heat in the coal, you can often place the blame for increased losses.

Unless plant testing extends over a fairly long period, it is difficult to estimate any differences in operating costs due to different coals. Items like increased power cost for handling or pulverizing can be measured easily but differences in maintenance costs will not show up for some time and then must be analyzed carefully to be sure they result from some property of the coal.

Normally analysis and testing will yield several coals having nearly the same value, any one of which will prove economical. Even under present price-fixing arrangements, relative coal values will change. Likewise plant conditions change, sometimes in equipment, but more often in the amount and nature of the load. These changes necessitate constant revision of the plant analysis and the coal selection data.

Check List of Furnace and Firing Conditions Affecting Coal Selection

FURNACE:

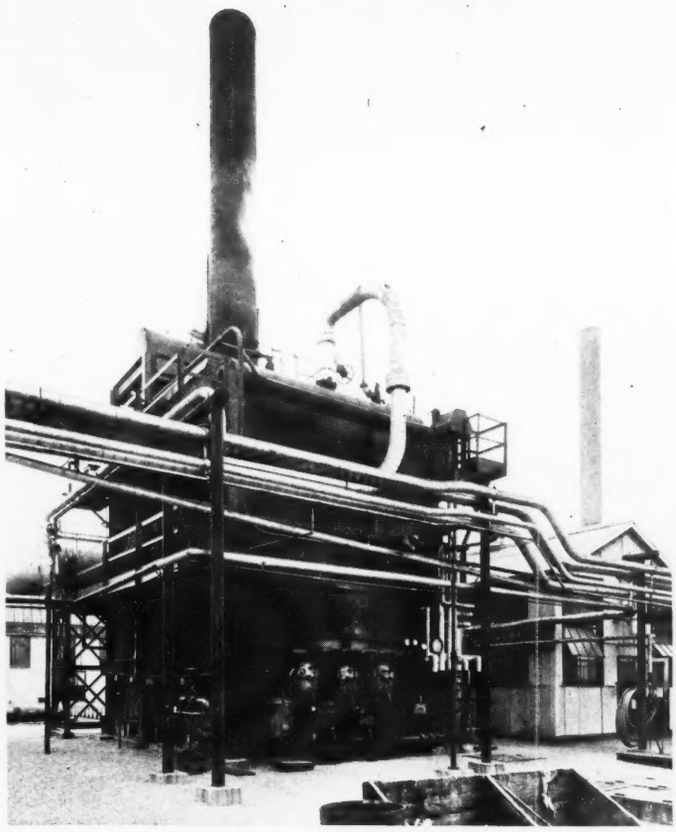
- Is volume ample for conservative heat release per cu ft?
- Can flame travel required distance without striking tubes?
- Does lack of refractory surface make ignition difficult?
- What is furnace temperature just ahead of first tube row?
- What is temperature in combustion zone?
- Does furnace shape promote turbulence and mixing?
- How much air preheat, if any?

STOKER:

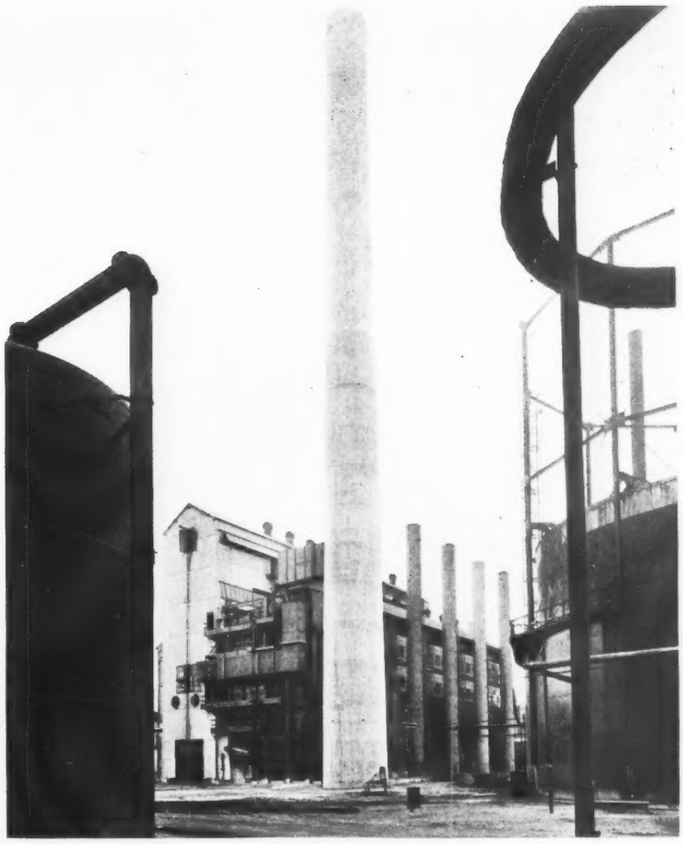
- What is general stoker type?
- How much agitation does fuel bed get?
- How well can underfire air be distributed and controlled?
- Is there enough overfire air and at the right places?
- How much do coal size and coking quality affect fuel bed?
- Does stoker distribute coal properly over fuel bed?

PULVERIZED-COAL FIRING:

- Is mill capacity ample to handle low grindability coals?
- What is grinding cost per ton, including parts replacement?
- Does inadequate drying capacity limit moisture content?
- Does amount and location of water-cooled surface restrict use of low-volatile fuels?
- Is furnace dry bottom or slag top? What range of ash-fusion temperatures insures satisfactory operation?
- Does furnace bar high-ash fuels requiring long flame travel?



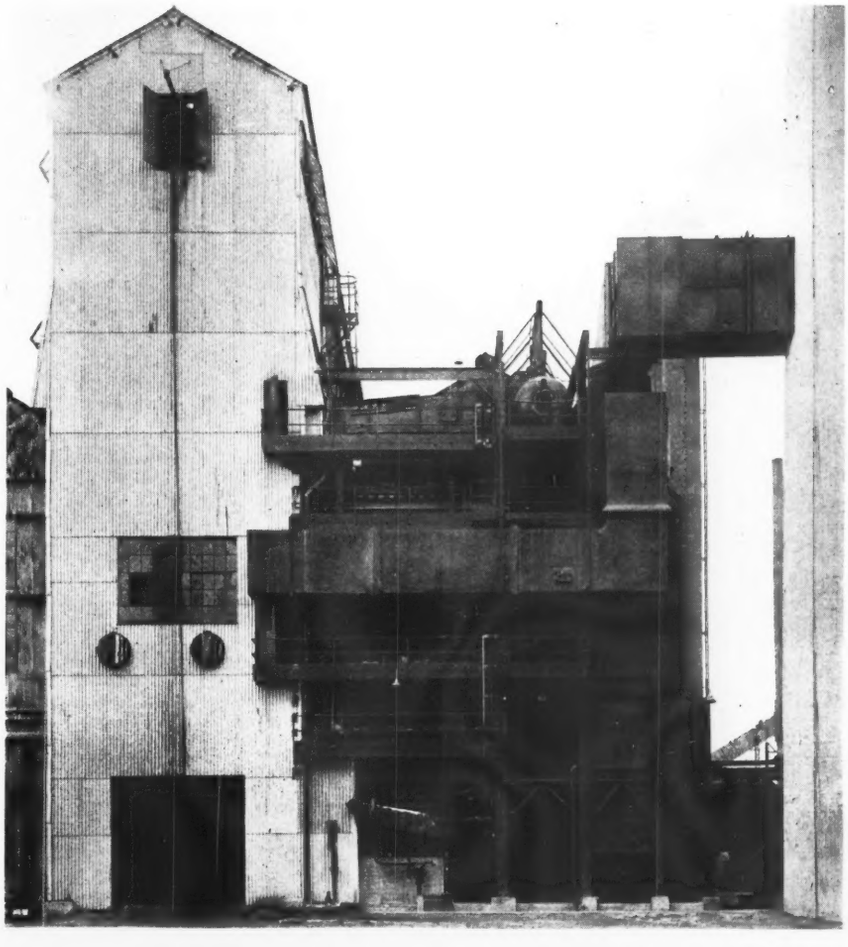
The first boiler (installed five years ago) is completely out of doors with not even a canopy over the burner front. This unit has operated successfully since 1935



New outdoor Riley boiler for Shell Oil Co's Wood River (Ill.) refinery is a 125,000-lb-per-hr unit complete with water-cooled furnace, steel-clad insulated setting and Riley tubular air heater

Wood River Opens Up

▶ BACK IN 1935 the Shell Oil Co. at its Wood River (Ill.) refinery installed one of the first completely outdoor boiler installations in the North. This consisted of one 5840-sq-ft Riley boiler with water-cooled furnace and proved so successful that Shell decided to add another unit in 1939. As an interesting sidelight, engineers report that it was approximately 15 deg below zero the day the boiler was placed in operation January of this year.



The new steam-generating unit operates now at 160 lb superheater-outlet pressure and 575 F total steam pressure. However, it is designed to operate in the future at 650 lb and 750 F

SHE DOESN'T KNOW—BUT YOU SHOULD

How can you protect your children from goitre? The best answer is *Worcester Iodized Salt.* The Council on Foods of the American Medical Association states: "Iodized Salt used daily as the only salt on the table and in cooking richly supplements the iodine of diets deficient in that element and thus helps to protect against simple goitre." So be sure you insist on Worcester *Iodized* Salt.

Worcester Salt Co., *America's oldest refiner of pure salt,* New York, U. S. A.

TRADE MARK Rx REGISTERED

Worcester Salt Co. obtains Iodized

WORCESTER IODIZED SALT — ACCEPTED AMERICAN MEDICAL ASSN Council on Foods

"It takes the best to make the best"

That has always been the Worcester Salt Company slogan. It takes the best salt and other ingredients to make the best food products and likewise it takes the best equipment to make the best salt as economically as possible. Worcester Salt Company state that is why they use Riley equipment.

Under the date of August 6, 1940, Worcester Salt Company writes as follows:

"It takes the best to make the best. It takes the best salt and other ingredients to make the best food products, and likewise it takes the best equipment to make the best salt. That is why we use Riley equipment."

Worcester Salt Company installed their first Riley Pulverizers in the spring of 1927.

The Worcester Salt Company are obtaining excellent results from the 150,000 lbs./hr. Riley "RP" Boiler Unit, they recently installed at their Silver Springs, N. Y., refinery. As has been the case with installation after installation, this unit went on the line without even minor starting-up difficulties; is giving complete satisfaction and is operating at better than guaranteed results — actual efficiency is 87.3% against a guarantee of 86.4%.

Riley has climbed to a position of leadership in the boiler and fuel burning industry because Riley design and workmanship assure absolute dependability and outstanding results—because of the plus values in Riley equipment —because purchasers have found that Riley surely gives them their money's worth.

When you consider additional steam generating or fuel burning equipment, it will pay you to investigate Riley equipment. A thorough inspection of recent Riley installations will definitely establish the superiority and great value of Riley equipment.

RILEY

STOKER CORPORATION, Worcester, Mass.

Boston New York Philadelphia Pittsburgh Buffalo Cleveland Detroit Tacoma
Baltimore St. Louis Cincinnati Houston Chicago Milwaukee Denver
Memphis St. Paul Kansas City Los Angeles Atlanta New Orleans

A survey of your power plant by a consulting engineer will possibly show ways of making surprisingly large savings in power costs.

COMPLETE STEAM GENERATING UNITS

BOILERS • PULVERIZERS • BURNERS • STOKERS • SUPERHEATERS
AIR HEATERS • ECONOMIZERS • WATER-COOLED FURNACES
STEEL-CLAD INSULATED SETTINGS • FLUE GAS SCRUBBERS

It will pay you to visit modern Riley Installations

WORCESTER SALT COMPANY

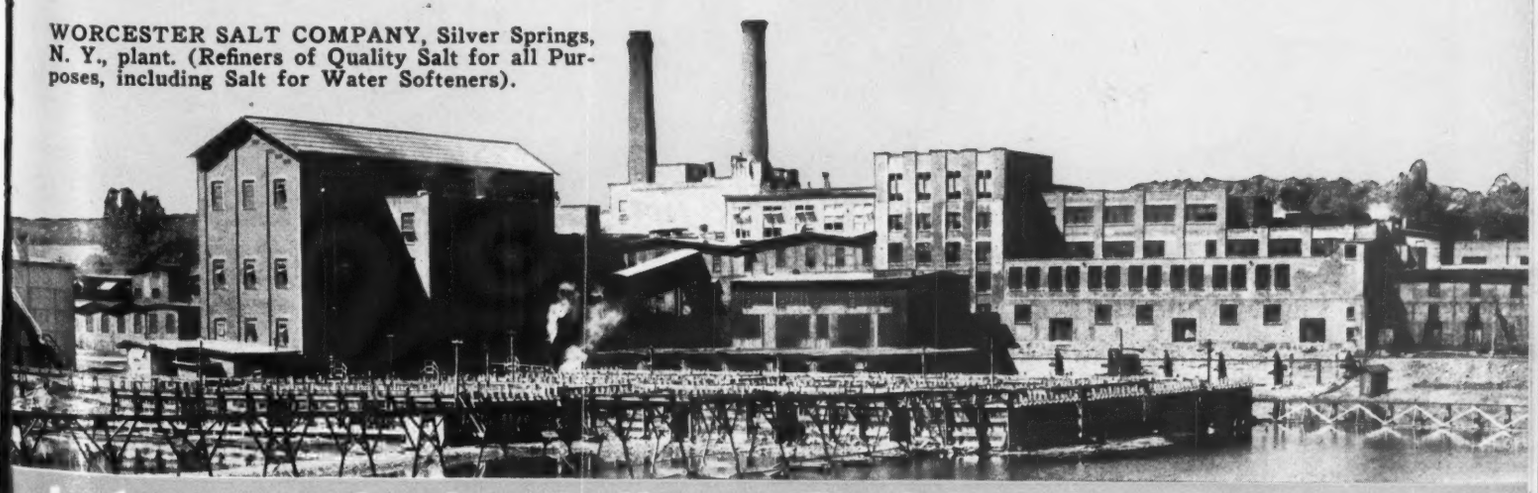
SILVER SPRINGS, N. Y.

Complete Riley Steam Generating Unit

Capacity 150,000 lbs. of steam per hour. Efficiency 87.3%. Unit equipped with Riley Boiler, Superheater, Water Walls, Air Heater located at side of unit, Steel-clad Insulated Setting, fired by Riley Pulverizers and Riley Burners

excellent results from Riley Boiler

WORCESTER SALT COMPANY, Silver Springs, N. Y., plant. (Refiners of Quality Salt for all Purposes, including Salt for Water Softeners).



before purchasing Boiler or Fuel Burning Equipment

Bypass Through Boulder

Fig. 1—Water spouting from twelve bypass needle valves in a recent test at Boulder Dam. This view from canyon wall below the dam looking toward Lake Mead

▶ BOULDER DAM and powerhouse never cease to attract attention. Recently, when twelve bypass needle valves were tested, more than 20,000 visitors, a record for a single day, witnessed the majestic spectacle, Figs. 1 and 2. Six valves high up in each canyon wall below the power plant bypass water around the dam to supplement discharge through the power units, when this is necessary.

In Fig. 2, the mighty water jets are seen from the power house shooting out at each other across the canyon. Above the jets, on a platform supported from an overhead cableway, are a group of engineers observing action of the water.

By the end of this year Boulder power plant will have installed ten 115,000-hp and one 55,000-hp main units, and two 3500-hp service turbine-generators—a total of 1,212,000 hp, making the plant the largest in terms of capacity in the world. Recently contract for the eleventh 115,000-hp unit was let; General Electric will build the generator and Allis-Chalmers the waterwheel.

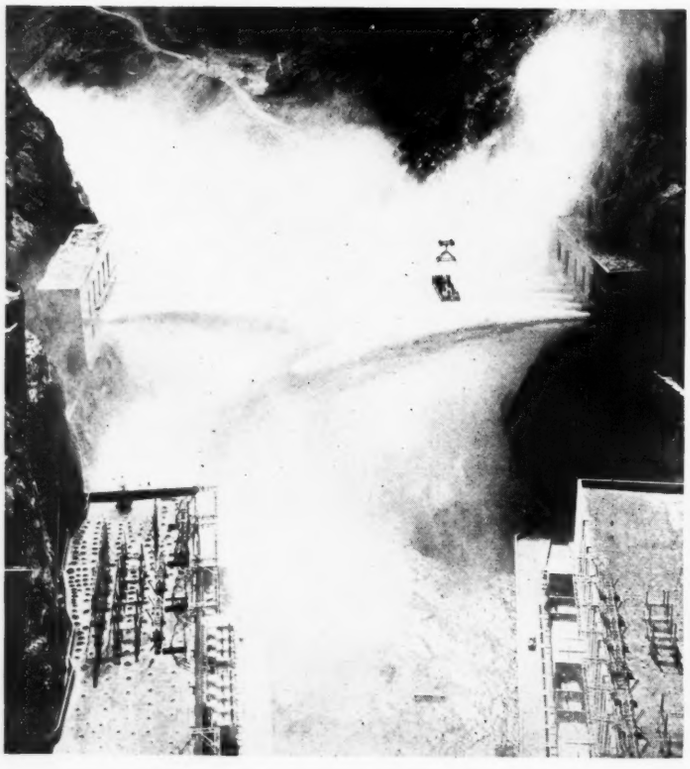


Fig. 2—Engineers observe action of the mighty cataracts during needle-valve test. Photo taken looking downstream at the powerhouse from top of Boulder Dam

Fig. 3—Early morning sun illuminates the generator gallery in the Nevada wing of Boulder Dam powerhouse. Its 1,212,000 installed hp make it the largest-capacity plant in the world

THE OLD CHIEF

II—The Horse With the Scarred Knees

Second in a series of reminiscences by William Doran, chief engineer, Essex County Sanatorium, Windsor, Ontario. Writing of the inspiration of the past, he has captured much of the human side of engineering that lies beneath the maze of power-plant costs and the waving lines on paper disks

The Chief brings in a visitor and finds a rip-roaring euchre game in full song

▶I REMEMBER that sometime after I had parted company with the Old Chief, he asked me to recommend an engineer for maintenance and relief work. I did so, and later when I found that my nominee had not been hired I was intrigued as to why the Old Chief had turned him down.

At our next meeting he thanked me for sending along the man. "You know, son," he said, "my old dad was a horse trader and he would never buy a horse that had scars on its knees. He figured a horse that had fallen down a few times was likely to fall again.

"Well, that man you sent me lost a finger and fell off a ladder when he worked at the packing plant, was badly scalded at the rubber works and fell off another ladder when he worked at the mill. So I guess he is just like the horse with the scarred knees—just plain unlucky to have around."

As I have mentioned before, the Old Chief spent many years in the merchant marine and he never for a moment forgot the many traditions of that service. For instance, the three engineers in the pump room were "Slim", "Hank", and "Shorty" to everyone in the plant except the Old Chief. To him they were always Mr Hosegood, Mr Appleby and Mr Hollings. A fireman, on securing his engineer's certificate, became Mister from that day on.

One night the Old Chief was returning from downtown about midnight in the company of a young man recently graduated as an electrical engineer. As they were passing the plant, the Old Chief invited his companion to step inside and see a new synchronous motor just installed to achieve power-factor correction. Unfortunately, the moment coincided with the time that the firemen, water tenders and other help around the power house had selected (against all rules) for a community lunch time, and a rip-roaring euchre game was in full song.

The Old Chief walked with his friend through to the engine room and discussed the new motor for a few minutes. He then introduced the senior engineer to his friend and as he was leaving he called the engineer aside and said, "By the way, Mr Brown, you will kindly give each of the men on your shift a written copy of the rules regarding relief at meal times. Also, arrange for the spare engineer to relieve each man one week in order that he may have time to obtain a full understanding of the rules.

"I also regret that I will have to 'log' you for this, Mr Brown. You should know that a boiler room is a place for work, not for play. There are ample facilities in this town for those who wish to play and this is not one of them."

The Log Book

I can assure you that there were no more roaring euchre games in that plant. And this personal "log" book was not a myth by any means. If an engineer's neglect or omission was the cause of an outage in any of the services, or if any action of his endangered a fellow employee, he was duly booked in the log.

There was the case of a man who placed a 125-lb valve in a line carrying 300 lb. Luckily the boner was discovered in time to prevent flying brass. Another entry involved a man who failed to mark and lock the switch on a 550-volt line on which men were about to work.

Every entry in the log book had its own story. For instance, we used a lot of hot water for process work and the water that had passed through a large ammonia condenser was used as feed for the hot-water tank. One afternoon a leak developed in one of the condenser tubes, which in turn brought an unpleasant surprise and tears to the eyes of all users of hot water in the entire factory. For some reason the engineer in charge failed to isolate the trouble promptly, and so he was booked for "incompetence in emergency."

There were two names that carried the notation "work shy" and one dubbed "trouble maker." Entries of this nature were the exceptions; most were such as "Left on this date to better himself. A man of good character, worthy of greater responsibility."

Some years ago the Old Chief was called to serve the Great Chief up above and I know the entry there is, "A competent man of good character—worthy of greater responsibility."

Operating Experience With a Slag-Tap Furnace

John P Topolosky, steam engineer, St Croix Paper Co, Woodland, Maine, reports results of four years' operation of a slag-tap furnace under a high-pressure boiler

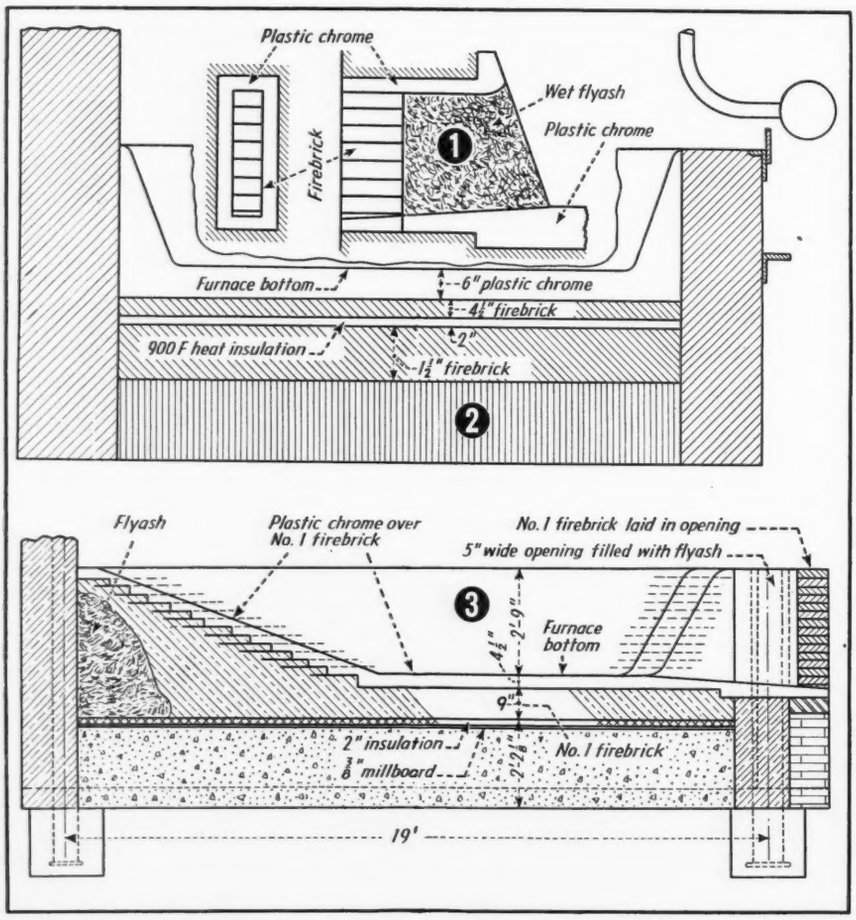


Fig. 1—Cross-sections through slag-tap hole in furnace. Fig. 2—Original slag-tap furnace bottom. Fig. 3—Redesigned slag-tap furnace bottom

► ABOUT FOUR YEARS AGO it became advantageous for us to use a low-grade coal containing 3.97% sulphur, 15.5% ash, fusing at less than 2000 F and that became fluid at 2300 F. Previously we had been burning a high-grade coal in pulverized form in a dry-bottom furnace with side and rear walls water-cooled. After some experimenting we decided that, because of the low ash-fusing temperature, the low-grade coal could be burned only in a slag-tap furnace. Construction of this furnace was described in January, 1939, POWER, page 90. Since that time we have had several interesting experiences.

Fig. 2 shows a cross-section through the original furnace bottom, which served for about two years and then had to be renewed. In this design the slag had a tendency to hang back on the furnace floor when it was drained to a low level. To overcome this difficulty the side and back walls of the furnace bottom were given a long slope toward the slag-tap hole, see Fig. 3. This new design, combined with operating improvements, has worked very nicely and is being used under a new boiler now being installed, rated 150,000 lb per hr at 450 lb and 725 F total temperature.

The front wall of the dry-bottom furnace was rebuilt and the two burners set to point inward and downward at an angle of about 8 deg. To insure high enough temperature at the slag-tap hole, the burners were arranged to rotate the flame inward. This directed the flame downward over the center of the slag-tap hole and then outward and upward along the furnace sidewalls. We were of the opinion that the flame should lap the slag pool, but have found that this is objectionable and unnecessary.

Operating Troubles Cured

We used to have trouble with miniature explosions in the slag as it flowed from the tap hole. These explosions caused small pieces of slag to fly in every direction. We eventually found that if the flame was not allowed to contact the slag these explosions would not occur.

We also had considerable trouble with flame erosion of the side and rear walls. This difficulty has been practically eliminated by adjusting the burners to keep the flame away from the walls. When doing this we try to keep the flame uniform across the furnace so as to blanket the slag pool from black surfaces of the boiler. To do this successfully the ignition head around the burners must be kept free of slag.

Proper pulverizing of the coal is an important factor in the successful operation of a slag-tap furnace. Particles of coal too large to be completely burned in suspension burn on their outside, become encased in a solidified slag shell, and fall into the slag pool. These

particles seem to require a higher temperature to melt than that of the molten slag and form an accumulation in the slag pool that looks like hot sand. This material hinders the free flow of the slag from the furnace and should be avoided by keeping the pulverizers in first-class repair.

Our slag-tap system is of our own invention and very simple, but it has worked very well. It consists of a slot 5 in. wide a little higher than the top of the slag pool in the front wall of the furnace bottom. This slot is closed by firebrick laid flat and backed up with wet flyash, as in Fig. 1. To tap the furnace we take out one brick at a time and dig out the flyash until the slag flows and is carried away in a stream of water. When the slag-pool level drops another brick is taken out to maintain a good flow. Two men can tap the furnace with less concern than wheeling out a barrow load of ashes.

Now we come to what for us was the most important factor in operating a slag-tap furnace, namely, correct temperature. In our early experiments we recognized this requirement. By using a portable optical-pyrometer-type temperature indicator we tried to find a relation between percent CO_2 and furnace temperature, also between steam-flow and air-flow and temperature that was accurate enough for our conditions. After extensive study we came to the conclusion that neither CO_2 or steam-flow-air-flow relation could be depended upon as an accurate furnace-temperature guide and decided to go to direct measurement with a radiation-type recording pyrometer.

Recording Pyrometer

This recording pyrometer, a Leeds & Northrup thermotube unit, has as its hot element a thin-walled refractory tube that extends through the furnace wall about 6 in. into the furnace. The end of the tube is closed and its outside end is open with a lens and thermocouple assembled in front of it. Radiant heat rays from the closed hot end of the tube pass through the lens and are concentrated on the thermocouple, which generates a voltage to actuate the recorder. With this system the lens and thermocouple are outside the high-temperature zone; therefore operate comparatively cool and have a constant calibration.

This instrument has taken all the guesswork out of operating the furnace. The operator knows that as long as he regulates the furnace to maintain a reading of 2300 F on the instrument, the slag pool will remain molten and the furnace walls will not be damaged. This also means that he keeps out of trouble and gets a pretty straight furnace-temperature curve.

We have found that it requires a considerably higher temperature to liquefy the slag after it cools than it does to keep it liquid. The liquefying temperature seems to increase with each cycle of melting and solidifying. Therefore, it is important that furnace temperature be maintained at a point that will keep the slag liquid. We feel that all our operating problems have been licked and the operators prefer the present set-up to the dry-bottom furnace.

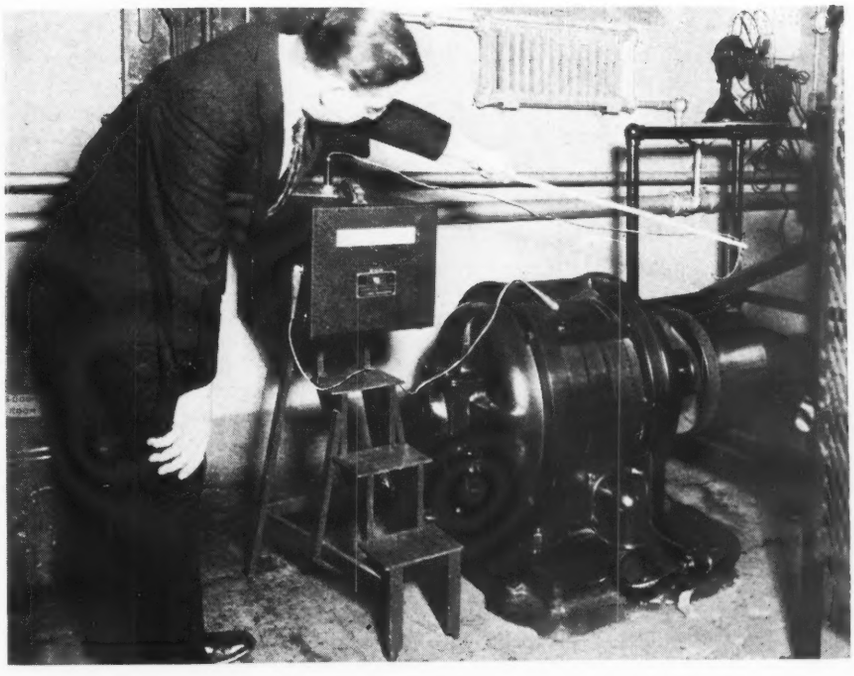
✦ ✦ ✦

Voltmeter Detects 37,000 Volts on Motor Belts

▶ STATIC ELECTRICITY in a powder plant can be a very dangerous hazard, so a well-known chemical company recently conducted tests with a General Electric electrostatic voltmeter to find out the extent of the static electricity generated on their conveyor belts, motor-drive belts, rubber-tired trucks, and from actual walking on floors. Checking the V-belts of a 25-hp motor, the 20,000-volt static voltmeter went off scale. Observation of the discharge spark indicated approximately 37,000 volts on the V-belt. Another test indicated that 6000 volts were generated simply by walking across the carpet of an office.

These preliminary tests led to more extensive checks in all of the chemical company's plants. As a result, belt dressings were investigated to find one of a conducting nature that would permit a continuous discharge of accumulated static electricity. All trucks were equipped with grounding chains, various types of flooring were investigated, and many other changes were made to minimize the hazards of explosion from static electricity.

The electrostatic voltmeter used in detecting the static is a 20,000-volt portable instrument designed for both alternating- and direct-current measurements of voltage on systems where one line is grounded. Operation is simply a matter of grounding the case, energizing the light source, and making the high-voltage connection. The photo shows an electrostatic voltmeter being used to measure the voltage on a motor belt in a large manufacturing plant.



Back to Air Injection?

Have mechanical handicaps pushed Dr Diesel's ideal—the air-injection engine—into the background? Warren Noble thinks so, and from a long career as a consultant on out-of the-ordinary engineering problems, presents here some unusual thoughts on air-injection design. You'll probably want to argue with his unconventional conclusions (we did) but you'll find they open new and interesting avenues for thought

By WARREN NOBLE
Consulting Engineer

▶ THE COLUMNS OF POWER refer with regularity—properly speaking, with irregularity—to "diesel" engines. Actually, there are relatively few true diesels in the USA, and I think none now in manufacture. Engines injecting fuel to the combustion chamber by jerk pump are *compression-ignition* engines having characteristics of their own definitely apart from the maintained-pressure principle evolved by Dr Diesel.

He would be the last man to countenance the use of his name to designate a type he deprecated. Though, as a good engineer devoted to research, he made experiments with solid injection, he continued to the last to extol the virtues of his original air blast for fuel delivery. I shall speak of diesel engines and principles only when dealing with such engines and refer to those using solid injection as CI engines.

Dr Diesel's Aim

Diesel definitely aimed at maintaining the compression-pressure peak over a period of working stroke consonant with load, but without increase in pressure. While the CI engine would like to—and does at times—approach the same desirable condition, it cannot avoid some rise in pressure at the beginning of fuel injection. The diesel engine depends on a supply of air, compressed beyond the pressure generated in the cylinder on the compression stroke, to atomize and deliver into the combustion space fuel metered to an open nozzle.

In the CI engine, a hydraulic pump drives the metered fuel directly into the cylinder, atomization being accomplished by expenditure of energy at the injection orifice. This latter point is highly important, rarely recognized, and responsible for a great many of the CI engine's vagaries. This is not to say that air injection is without its foibles too, but they are due far more to causes exterior to the cylinder, in fact almost entirely so.

If we imagine two engines similar in all respects except as to this injection business, we can compare the practical setups best by contrasting the difference in the auxiliaries devoted to injection and starting. In the case of the diesel, we must have an air compressor capable of creating a reserve of air at substantially double the engine-compression pressure, the distributing valve gear necessarily located at each cylinder, and the injection nozzles. The compressor need not be large. It will provide power for starting, but must be alternately driven or paralleled by a separate compressor if the engine is large. There must also be a metering device operating at low pressure.

The CI engine must have a starting system. If this is pneumatic, it requires a compressor as for the diesel, although high-pressure capacity is not needed; if electric, a high-torque motor, storage batteries and a charging generator are required. There must be nozzles at the cylinders, to which the metered fuel can be piped, and there must be a high-pressure metering hydraulic pump.

In everyday practice this metering pump is looked upon as the heart of the engine—actually it can be rated only in company with its nozzles since final performance depends on the end result of pump and nozzle in combination. Usually the complete assembly is purchased from a specialist manufacturer who supplies—and so types for performance—injection systems for many engine builders. The manufacture of such a metering pump and nozzles is probably the highest expression of associated precision parts extant. Few organizations can aggregate the necessary skill to make and maintain the necessary quality of mechanism, and the cost of these units constitutes an important element of engine cost.

In the diesel proper, the metering function needs to be held to corresponding accuracy, although high-pressure delivery is not involved. Actually there is little advantage or comfort in this pressure change since metering of a viscous liquid such as fuel oil involves a quality of workmanship beyond normal, so far beyond in fact that the high- or low-pressure factor can be neglected.

Air-Compressor Problems

Construction of multi-stage air compressors capable of reliable operation over long periods of time, while delivering air in the neighborhood of 1200 lb per sq in., is a task of no mean magnitude. The history of the diesel engine in practice is a long record of air-compressor problems. Valve gear and nozzles in general present no difficulty, so that in the end we find the true diesel picture dimmed by compressor difficulties.

Now, the quality of diesel or CI cylinder performance depends directly on the quality of fuel atomization. Improve distribution of fuel through the air charge and the performance will improve correspondingly. The fuel as it leaves the nozzle hunts oxygen, the surrounding air is heated, and power generation begins. Each drop of fuel

burns on its own; acts like a burning bullet. But unfortunately, as it burns it surrounds itself with a jacket of burned gas, slows down on its oxygen hunt and even has difficulty satisfying its fire-feeding hunger.

If We Had a Dual Fuel

It would be plain sailing if a droplet of fuel could be made to act like a rocket, once fired self-propulsive. Or, if we could only use a dual fuel in which a coat of slowly combustible oil contained a nucleus of highly evaporative inflammable. The initial combustion would cause the nucleus to burst through the coating, scattering it in all directions. In other words, if we could arrange for the particle or droplet of fuel to carry some dispersive energy along with it, combustion would change markedly for the better. As things are now, the work done by the jerk pump expends itself first in atomizing the oil indifferently well, leaving but little surplus energy to secure penetration into the dense air of the combustion chamber.

It is this part of the picture that turns me back to Diesel's method where the metered mass of oil is atomized and carried along by high-velocity air. The final droplet is definitely finer, which means more surface available to the hungry air, although on account of the expansion of the carrier air it is robbed of some heat. However, this air has to come through the nozzle, and so picks up some heat to help regenerative action. The expanding air, moreover, has potential energy with which to carry oil droplets along, rolling them tornado-wise like a barrel in the rapids. Furthermore, a high degree of combustion-space air turbulence is set up, in addition to the turbulence inherent in the space form and aimed at by the engine designer. Even the cooling effect of the injection air has beneficial function in fighting detonation—the bugbear of CI-engine as of gasoline-engine design.

A New Compressor Design

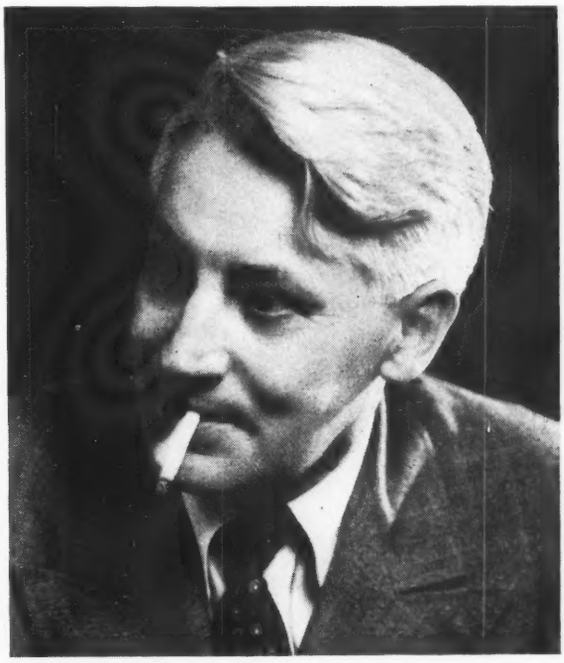
I am perfectly convinced better atomization and better all around performance lie ready to command in the air-injection engine. This is in the face of the facts, which begin and end with a wide collection of satisfactory engines of which none employs an air blast for injection purposes.

To my way of thinking, the compressor is to blame for the trend away from the air-injection engine. It represents another complication for designer and operator alike. But let's see whether we might not be able to get along without said compressor in its conventional form. If we start to design an independent compressor for 1200-lb air, we certainly need three, and probably four, stages. However, the condition is different when we design a compressor for a diesel engine, because we already have available within each cylinder a perfectly good compressor, working up to the equivalent of the third stage of any compressor we might build.

Suppose then—remember I'm simply thinking out loud—we bleed off from our combustion space, just prior to injection, or after, for that matter, a small quantity of air sufficient for the nozzle blast. Let's run it through an intercooler (the conducting pipe will probably be plenty good enough to drop temperature) leaving pressure at about 400 lb. Let's make a combination nozzle and measuring pump, fed from a common rail, and a step-up air cylinder drawing its charge from the 400-lb cooled air bled from the main cylinders themselves. Let's operate the combination pump, nozzle and compressor from the camshaft, with a lift and rocker arm, just as we now do the valves or the injection lift on any present-day common-rail system.

Down will go the rocker, super-compressing the bled air to whatever we need in the way of blast pressure; at the right moment, let trapped high-pressure air and measured fuel through to the combustion space. We should have everything the diesel system gave us, less the unit compressor and with no more valve gear than we normally have today. Certainly we shall have provided some extra turbulence, arranged for better atomization than a direct jerk-pump-fed nozzle can give us, and saved a lot of compressor mechanism. We shall need a bigger main cylinder—infinitesimally so dimensionally speaking—with a slightly higher prime compression ratio. But don't forget some of the energy of the injection air is recovered on the working stroke; it's not all loss by any means.

The more I think of it the better I like it. I believe the scheme would relieve the CI sluggishness as compared with the true diesel, get rid of nozzle troubles and be adaptable for use in small engine sizes (in which the volume of business lies), never within reach of true diesel methods.



Warren Noble, pioneer in many an engineering exploration, including design of early engines for automotive and aircraft use, rarely follows the beaten path. His views are always original and stimulating, often highly controversial, as here. We present his statements, not because we fully agree, but because what he has to say is a challenge to discussion and debate.

Engineering V-Belts to Suit the Drive

F L Ives, engineer, Allis-Chalmers Mfg Co, lists simple rules for selecting multiple V-belts and shows how to apply them to get the size drive that will give long satisfactory service

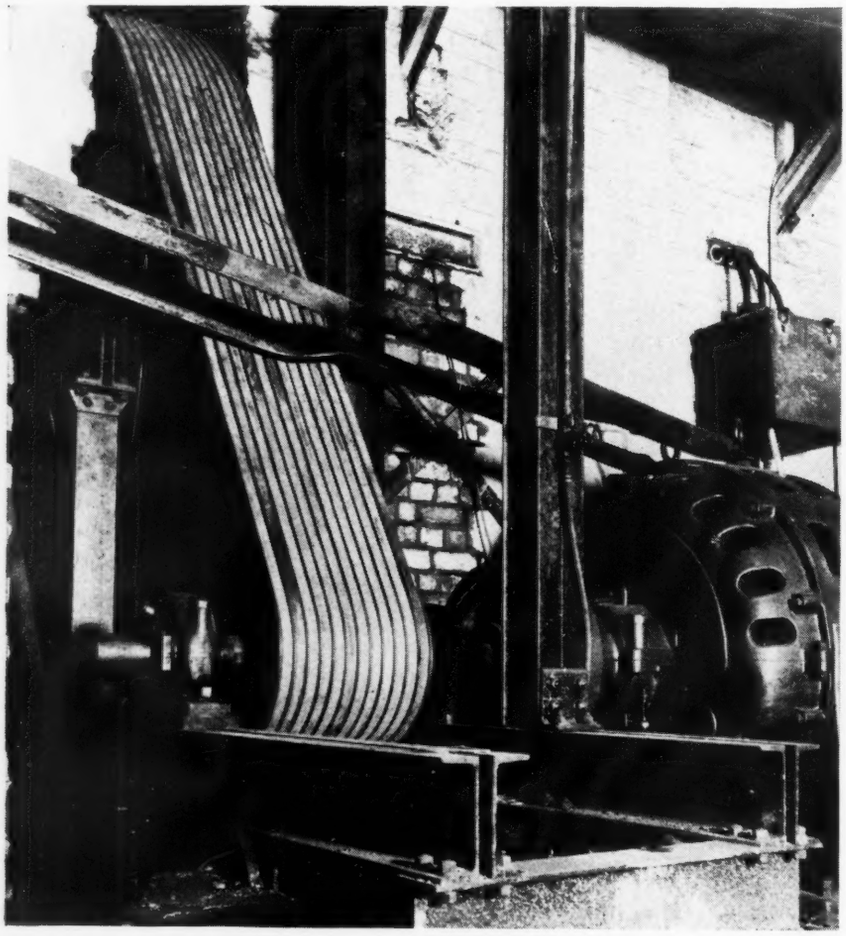


Fig. 1—A 200-hp, 575-rpm induction motor drives line shaft at 100 rpm through a 12-strand multiple V-belt in a grinding shop

► MOST APPLICATIONS of power require some form of speed reducer, such as a multiple-V-belt, between motor and driven machine. These belts, like all mechanical-power-transmission equipment, must be properly engineered to suit the drive, if the most economical installation and satisfactory service is to be obtained. Correct selection of these belts, for the average installation, is comparatively easy if a few simple but important rules are followed.

V-belts are made in several constructions, but the design, Fig. 2, is typical. The belt consists of a top or tension section made of layers of bias-cut cotton fabric laid transversely and well impregnated with rubber compound. This layer is given the necessary stiffness to prevent the belt from buckling, but at the same time it has sufficient elasticity to bend under tension around the sheave.

Center Section

The center or power-transmitting section is made of a number of layers of long-fiber cotton cord. The number of cords per layer and the number of layers depend on the size of the belt. Below this layer of cords is a compression layer, compounded in such a manner that when the belt is bent over a sheave, the neutral axis will develop at the most advantageous point. This layer is composed of different constructions in different belts. Several belts use compounded rubber. Some use rubber and a filler of loose, high-crimp cotton weave. Others use rubber and cotton cords.

As a rule, the belt carcass is covered

TABLE I—NORMAL HORSEPOWER RATING OF SINGLE V-BELTS

Belt Speed, ft per min.	A-Section Belts — Pitch Diameters, in.							B-Section Belts — Pitch Diameters, in.						C-Section Belts — Pitch Diameters, in.					
	2.6	3.0	3.4	3.8	4.2	4.6	5.0*	5.0	5.4	5.8	6.2	6.6	7.0*	7.0	8.0	9.0	10.0	11.0	12.0*
1000	0.5	0.7	0.8	0.9	0.9	1.0	1.0	1.3	1.4	1.5	1.6	1.7	1.8	2.0	2.5	2.8	3.1	3.4	3.6
1500	0.8	1.0	1.1	1.3	1.4	1.4	1.5	1.8	2.0	2.1	2.3	2.4	2.5	2.9	3.6	4.2	4.6	5.0	5.3
2000	1.0	1.3	1.5	1.6	1.8	1.9	2.0	2.4	2.6	2.8	2.9	3.1	3.2	3.7	4.7	5.5	6.1	6.5	7.0
2500	1.1	1.5	1.7	2.0	2.1	2.3	2.4	2.8	3.1	3.3	3.5	3.7	3.9	4.5	5.7	6.6	7.3	8.0	8.5
3000			2.0	2.2	2.4	2.6	2.7	3.2	3.5	3.8	4.0	4.3	4.5	5.0	6.5	7.6	8.5	9.2	9.8
3500				2.5	2.7	2.8	3.0	3.4	3.8	4.1	4.4	4.7	4.9		7.1	8.4	9.4	10.3	11.0
4000					2.8	3.0	3.3	3.5	4.0	4.4	4.7	5.0	5.3			9.0	10.2	11.2	12.0
4500						3.2	3.4	3.5	4.0	4.4	4.8	5.1	5.4				10.7	11.8	12.7
5000							3.4	3.3	3.8	4.3	4.7	5.1	5.5					12.2	13.2

* And larger.

with one or two layers of bias-cut fabric. This fabric takes the wear and helps to hold the belt together, but one manufacturer leaves this cover off.

V-belts are made in five sizes of trapezoidal cross sections, Fig. 3, designated *A*, *B*, *C*, *D* and *E*. Sheave grooves are made practically the same size as the belts, but are cut approximately $\frac{3}{16}$ in. deeper than the belts to prevent them from touching the bottom of the grooves. Standard stock drives are listed in speed ratios of from 1 to 1 to 7 to 1, but can be designed for speed ratios up to 10 to 1. They can be run in either direction with the slack strand on either top or bottom.

These belts are built up with rubber compound, and therefore cannot be operated for long in a temperature in excess of 180 F, or in contact with oil or oil spray. Belts made of a synthetic rubber compound are available for operation in the presence of oil. Multiple V-belts can run on sheaves set at right angles to each other, but parallel shafts give best results. Means must be provided to take up the slack in the belts due to stretch and to prevent their slipping in the sheave grooves.

Rating Tables

To assist in selecting V-belts, all manufacturers publish tables showing horsepower ratings of their belts for speeds up to 5000 ft per min. and running over different sizes of sheaves. Table I gives these ratings. Note that for a given belt speed, the larger the pitch diameter of the sheave the more power the belt will transmit. For example, a C-section belt at 3000 ft per min is rated 5 hp on a 7-in. sheave, 7.6 hp on a 9-in. sheave and 9.8 hp on a 12-in. sheave. Under each type of belt the rating given for the largest sheave also applies for larger sizes. For example, under *A*-section belts the largest sheave given is 5 in. in diameter. Use ratings for this sheave for all larger sizes.

The ratings in Table I are based on the assumption that the belts make a 180-deg contact with each sheave, as would be obtained when both sheaves are the same sizes. For most drives one sheave is smaller than the other so that a correction factor must be made for the arc of contact on the smaller sheave. This arc of contact can be easily determined by a simple formula

TABLE II—CONTACT-ARC CORRECTION FACTORS

(Where contact arcs are less than 180 deg, V-belt ratings are reduced as shown below)

Arc of Contact, Deg	*Correction Factor*	*Arc of Contact, Deg*	*Correction Factor*	*Arc of Contact, Deg*	*Correction Factor*
180	1.00	135	0.87	105	0.76
170	0.98	130	0.86	100	0.74
160	0.95	125	0.85	95	0.72
150	0.92	120	0.83	90	0.69
145	0.91	115	0.81	85	0.66
140	0.89	110	0.79	80	0.64

TABLE III—FACTORS THAT INCREASE HORSEPOWER OF V-BELTS

APPLICATIONS	Electric Motors										Engines		
	A C								D C				
	Squirrel Cage				Synchronous		Single Phase						
	Normal Torque Line Start	Normal Torque Compensator Start	High Torque	Wound Rotor (Slip-Ring)	Normal Torque	High Torque	Repulsion and Split Phase	Capacitor	Shunt Wound	Compound Wound	Gas and Diesel 4 or More Cyl Above 700 r p m	Steam	Line Shafts and Clutch Starting
Agitators — Paddle-Propeller	1.2	1.0	1.4	1.2	....	....	....	....	....	....	....	....	....
Brick and Clay Machinery	1.5	1.3	1.8	1.5	....	....	....	....	1.4	....	....	....	2.0
Bakery Machinery	1.2	....	....	....	....	....	1.2	1.0	....	....	....	....	....
Compressors	1.4	1.4	....	1.5	1.5	....	1.2	1.2	1.2	....	1.2	....	....
Conveyors	....	1.6	1.8	....	....	....	....	....	1.6	....	....	....	1.8
Crushing Machinery	....	1.4	1.6	1.4	1.4	1.6	....	....	....	1.6	1.6	....	1.6
Fans and Blowers	1.6	1.6	2.0	2.0	2.0	2.0	....	....	1.4	....	1.6	1.5	1.5
Flour-Feed Cereal Mill Machinery	1.4	1.4	1.6	1.4	1.4	....	....	....	....	....	1.8	....	....
Generators and Exciters	1.2	....	....	....	....	....	....	....	1.2	....	2.0	1.4	1.4
Laundry Machinery	1.2	....	....	....	....	....	....	....	....	1.2	....	....	....
Line Shafts	1.4	1.4	....	1.4	1.4	2.0	1.4	1.4	1.4	1.4	1.6	1.6	1.6
Machine Tools	1.2	....	....	1.4	....	....	1.2	1.2	1.2	1.2	....	....	....
Mills	....	1.6	1.6	1.4	....	....	....	....	....	1.4	....	....	1.6
Oil-Feed Machinery	1.2	1.2	1.4	....	....	....	....	....	1.4	1.4	1.4	1.4	1.6
Paper Machinery	1.5	1.4	1.8	1.5	1.6	1.8	....	....	1.5	1.5	....	....	1.8
Printing Machinery	1.2	1.2	....	1.2	....	....	....	....	1.2	1.2	....	....	....
Pumps	1.4	1.4	1.4	1.6	1.6	1.8	1.2	1.2	1.2	....	2.0	2.0	....
Rubber Plant Mach.	1.4	1.4	1.4	1.4	....	1.8	....	....	....	....	....	2.0	....
Screens	1.2	1.2	1.4	....	....	....	....	....	....	....	....	....	....
Textile Machinery	1.6	....	1.8	....	....	....	....	....	....	....	....	....	....

TABLE I (Cont'd.)—NORMAL HORSEPOWER RATING OF SINGLE V-BELTS

Belt Speed, ft per min	D-Section Belts — Pitch Diameter, in.						E-Section Belts — Pitch Diameter, in.								
	12	13	14	15	16	17*	20	21	22	23	24	25	26	27	28*
1000	4.5	5.1	5.6	6.1	6.5	6.8	8.0	8.5	9.0	9.4	9.8	10.2	10.5	10.9	11.1
1500	6.5	7.5	8.2	8.9	9.6	10.1	11.7	12.5	13.2	13.9	14.5	15.1	15.6	16.1	16.5
2000	8.4	9.7	10.7	11.7	12.5	13.2	15.2	16.2	17.2	18.1	18.9	19.6	20.3	21.0	21.6
2500	10.1	11.6	12.9	14.1	15.1	16.0	18.3	19.6	20.8	21.9	22.7	23.0	23.9	24.7	26.3
3000	11.4	13.3	14.9	16.3	17.5	18.6	20.9	22.7	24.0	25.3	26.5	27.6	28.6	29.6	30.5
3500	12.4	14.6	16.5	18.1	19.5	20.7	23.0	24.9	26.6	28.1	29.5	30.8	32.0	33.1	34.2
4000		15.5	17.6	19.4	21.0	22.5	24.5	26.6	28.5	30.3	31.9	33.4	34.7	36.0	37.2
4500				20.3	22.1	23.5				31.7	33.5	35.2	36.7	38.2	39.5
5000					22.6	24.4						36.2	37.9	39.5	40.9

* And larger.

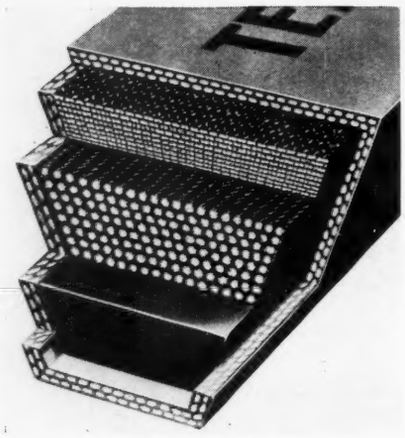


Fig. 2—Cross-section through a V-belt to show its construction

given later and then the correction factor in Table II is applied.

The kind of load, type of power unit and method of starting must be considered when applying V-belts. This is done by using service factors as given in Table III. To obtain the horsepower capacity for which a belt or a given drive must be selected, multiply the horsepower of the drive unit by the service factor corresponding to the condition under which it operates. For example, assume a 10-hp, normal-torque, line-start, squirrel-cage motor driving a fan. The service factor corresponding to these conditions in Table III is 1.6. Then, the V-belt will have to be selected for 10 × 1.6 = 16 hp motor.

How V-Belt Drives Are Selected

As an indication of how V-belt drives are selected, assume an air compressor requires 35 hp to drive it at full speed (300 rpm) and that a 40-hp 1160-rpm motor is selected. The size of the motor sheave is one of the first things to determine. Where possible, select a sheave with a pitch diameter that will give a belt speed of around 4000 ft per min, as this is an economical speed. Pitch diameter D of the motor sheave equals 12 times belt speed in feet per minute divided by 3.14 times motor speed. Then $D = (12 \times 4000) \div (3.14 \times 1160) = 13$ in. With this size sheave we can use a D-section belt which at 4000 ft per min will transmit 15.5 hp, as indicated in Table I.

The air compressor is to operate at 300 rpm. Then the size of the compressor sheave equals motor speed times motor-sheave diameter divided by compressor speed or $(1160 \times 13) \div 300 = 50.3$ in. in diameter. A center distance between sheaves slightly larger than the diameter of the largest sheave and less than the sum of the diameters of the two sheaves will be found satisfactory for most drives, where other factors do not establish the limits. Longer or shorter centers are practical and are recommended where conditions require their use.

On high-speed drives, comparatively short centers are recommended. In our problem the sum of the two sheave diameters is 13 + 50 = 63 in. Therefore, we may assume a center distance of 60 in. This is the distance that should be between the two shaft centers when the motor is set nearest the compressor and the belts will slip on over the sheaves.

To select the number of belts in the drive, allowance must be made for the arc of contact that the belts make around the small sheave and the kind of load being driven, as previously mentioned. The arc of contact may be found by the formula:

$$\text{Arc of contact} = 180 - \frac{60\,(D-d)}{C}$$

where D equals diameter of large sheave, d diameter of small sheave and C center distance between sheaves. Then in this problem

$$\text{Arc of contact} = 180 - \frac{60\,(50-13)}{60}$$

$$= 143 \text{ deg.}$$

From Table II we see that on an arc of contact of 140 deg, the belt can transmit only 0.89 of its rated power, or 15.5 × 0.89 = 13.8 hp.

The characteristics of the power unit and of the driven load must also be considered. This is done by a service factor obtained from Table III. Assume that the motor is a normal torque, line-start, squirrel-cage type. With this type of motor driving a compressor the service factor is 1.4 and the belt will be selected for 40 × 1.4 = 56 hp. Each belt will transmit 13.8 hp, therefore we need 56 ÷ 13.8 = 4 D-section belts.

We now need to know the length of the belt, which can be determined by the formula:

$$L = 2C + \left[1.57\,(D+d)\right] + \frac{(D-d)^2}{4C}$$

where the symbols represent the same dimensions as previously given. Then

$$L = (2 \times 60) + \left[1.57 \times (50+13)\right] + \frac{(50-13)^2}{4 \times 60} = 224.7 \text{ in.}$$

say 225 in. The drive would then be written 4—D225—130—503, centerline 60 in. This drive will be economical and capable of applying the full motor load to the pulsating compressor load.

When ordering the drive it is best to select the nearest stock-length belt. In this problem we have the choice of a belt 213.1 in. or 240 in. pitch length. If the stock lengths are not known and the motor can be set a little closer or farther away from the drive, let the belt manufacturer know the amount of leeway you have and order a stock belt of a length nearest to the calculated one. Then when future belts are ordered they can be obtained directly from stock, which will insure quick delivery.

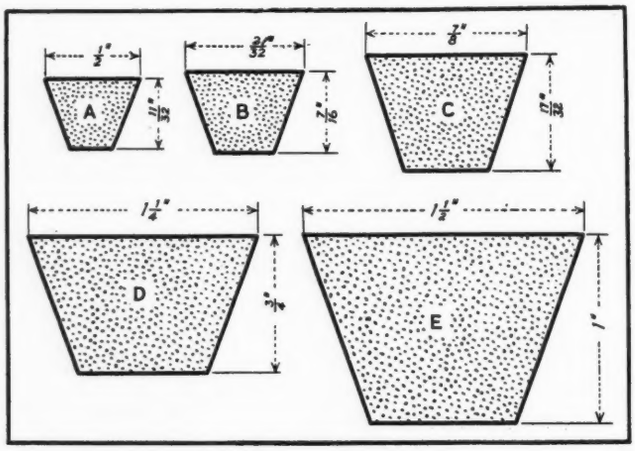


Fig. 3 — Outline cross sections of the five standard sizes of V-belts

Weight Slip

AN ANONYMOUS READER signing himself as "A well wisher" points out a slip in the last "Headwork Section", page 117, November POWER. Most certainly the weight of a cubic inch of water is .036 lb, not 0.36, as indicated. What makes my face red is that I multiplied 0.36 × 382,000 cu in. in the tank and got a total weight of water of 137,000 lb. Any dumbbell ought to know that a cylindrical tank 72 in. in diameter and 94 in. high won't hold 137,000 lb of water. I am asking all readers of the "Operating Engineer" to turn to page 117, November POWER, and correct this to read: 328,000 × 0.036 = 13,700 lb.—*PWS.*

THE OPERATING ENGINEER

George Edwards
Advisory Editor

Practical Aids
Maintenance Hints
Questions — Answers

Published monthly as an integral part of POWER

BRAZED LAP SEAMS ARE STRONG
If Made Right

ASME Code for Unfired Pressure Vessels allows 9900-lb-per-sq-in. working stress in shell plate for properly brazed longitudinal lap joints. Harry M Spring shows how joint is made, how to figure a joint for a given pressure, how to calculate safe pressure

BRAZING is frequently used to form the seams of compressed-air tanks and other pressure vessels for operating temperatures under 406 F. Temperature is a factor because the physical properties of brazing metal fall off appreciably at higher temperatures.

Among other limitations on brazing is the requirement that when the seam is lapped (customary, although butt and double-strap brazed seams may be used in plates up to 1 in. thick) the thickness of the plate shall not exceed $\frac{3}{8}$ in. This is according to the ASME Code for Unfired Pressure Vessels, which gives detailed specifications for brazed seams.

Preparing a plate for brazing requires that the metal be clean and free from paint, oil, scale or rust. The shell is then rolled to cylindrical form, with edges overlapping at least eight times the plate thickness (Fig. 1). The lap is then held tightly in position by "tack rivets" (Fig. 2A), stitch welds (2B), or plug welds (2C).

Tack rivets are small-diameter rivets, usually $\frac{5}{8}$ in. or less, spaced at a relatively large pitch, say 2 to 4 in. To eliminate hole drilling, and reduce cost, stitch welding is replacing other methods of "tacking" the seam.

Brazing rod and flux are applied to one side of the seam. Heating is usually by an acetylene torch. The braze metal is applied until it shows uniformly on the opposite side of the joint, indicating that the metal has penetrated the entire lap. Free use of flux is important to insure easy flow of braze metal through the lap. This complete penetration is essential, because a partly brazed seam may act as a "hinge" to break the brazed metal.

Any brazed pressure vessel in which the braze metal is not continuous on both inside and outside edges of the lap is dangerous, and should be taken out of service.

That the recognized rule-making body has confidence in the strength of a properly brazed joint is indicated by the Code allowance of a maximum unit working stress of 9900 lb per sq in. This means that the permissible maximum tank pressure is that which gives a unit stress of 9900 lb per sq in. in the metal outside the joint.

The standard tank formula (for all kinds of joints) is:

$$P = S \times t \times E \div R, \text{ where}$$

P = maximum allowable working pressure
t = minimum shell thickness in inches

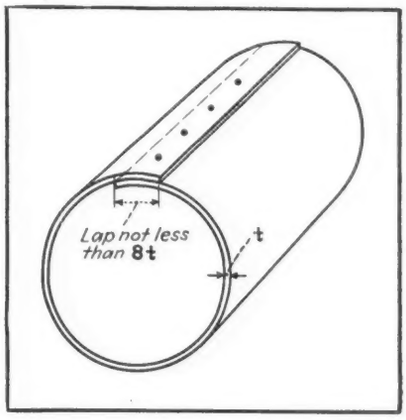


Fig. 1—ASME Code requires that the brazed longitudinal seam shall lap not less than eight times plate thickness

R = internal radius of the shell in inches
S = safe working stress in the plate
E = efficiency of the joint

In the case of brazed joints, $S \times E$ is considered a single term having a maximum allowable value of 9900 lb per sq in., so the formula becomes $P = 9900 \times t \div R$. Thus, if an air tank is $\frac{1}{8}$ in. thick, 20 in. in diameter, and has a properly brazed longitudinal lap seam, the construction warrants a maximum pressure of $P = 9900 \times 0.125 \div 10 = 124$ lb per sq in.

For existing tanks it is often convenient to transpose the formula to determine whether operating conditions are subjecting the seam to excessive stress. The formula then becomes actual working stress in plate $= P \times R \div t$. Given a 24-in. diameter air tank having a properly brazed shell of $\frac{3}{16}$ in. thickness. This tank operates with the safety valve set at 140 lb per sq in. Then

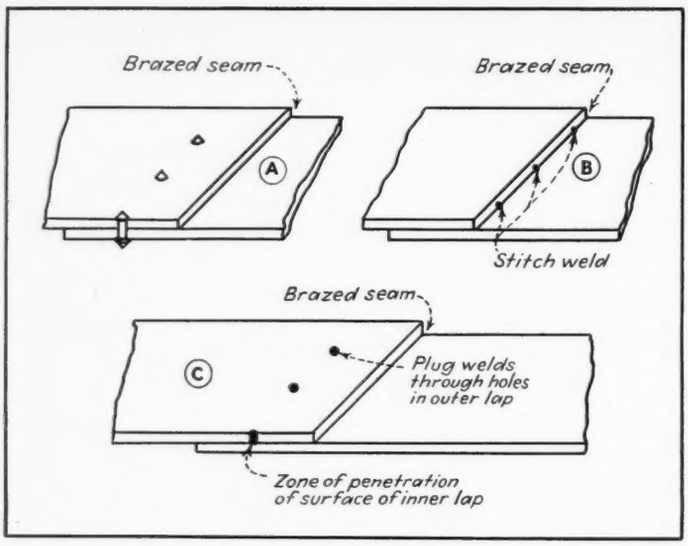


Fig. 2—Before brazing, seam is tightly bound together by tack rivets (A), stitch welds (B) or plug welds (C)

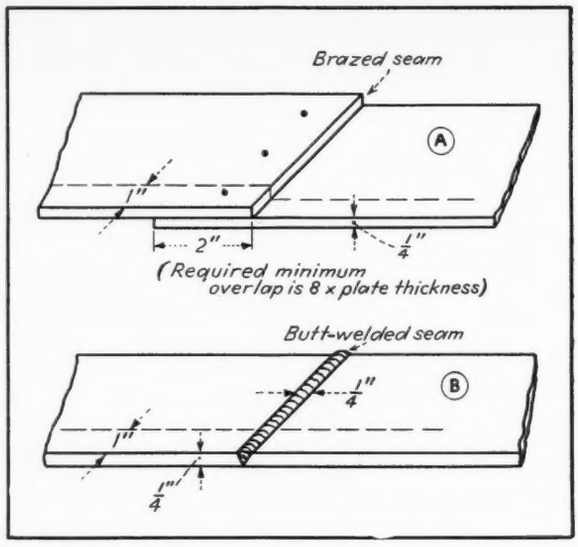


Fig. 3—Area of the braze metal in shear is eight times area of weld metal in tension

actual working stress in plate = 140 × 12 ÷ $\frac{3}{16}$ = 8960 lb per sq in. As this stress is below the permissible maximum of 9900 lb, the operating conditions, as based on the shell construction, are okay if the joint is soundly and completely brazed.

It is interesting to compare the strength of a brazed seam with a welded seam. Braze metal is in shear, and should have (as required by the Code) a minimum *shearing* strength of 10,000 lb per sq in. A butt weld is in tension; the usual minimum *tensile* strength of weld metal is 55,000 lb per sq in. Referring to Fig. 3A, we see that a 1-in. wide unit section of the brazed seam subjects an area of 1 in. × 2 in., or 2 sq in., to shearing stress, and that the ultimate strength of this should be 2 × 10,000 = 20,000 lb.

The butt weld in Fig. 3B is in a plate of the same thickness, but is in tension. The effective area of the weld in a 1-in. wide strip is 1 × ¼ = 0.25 sq in., and the calculated ultimate strength is 55,000 × 0.25 = 13,750 lb.

From this it can be seen that a properly brazed lap seam in thin plates (with lap at least eight times plate thickness) may be even stronger than a butt-welded seam, contrary to the usual impression. We should appreciate, too, that the stress of 9900 lb per sq in. allowed by the Code for brazed seams is actually equivalent to 90% joint efficiency, the same allowed for the highest class of welded seam, subjected to stress relieving and radiographic examination.

This conclusion is arrived at from the fact that the usual minimum tensile strength of the shell plate is 55,000 lb per sq in. Dividing this by the customary factor of safety, 5, we get 11,000 lb per sq in., which, multiplied by an "efficiency" of 90% results in 9900 lb per sq in. allowable stress.

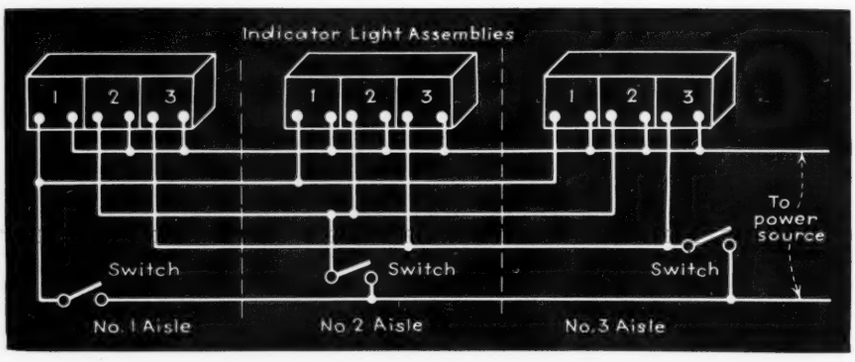
Lamps Signal When to Blow Down Boilers

IN OUR PLANT we have 18 stoker-fired boilers arranged three to a battery with two batteries facing each of three firing aisles. Each two batteries facing a firing aisle are operated as a unit which has its own operating crew. Blowoff connections from all boilers connect into a common header that discharges into the condenser circulating-water outlet canal. To avoid the objectionable effects of blowing down more than one boiler at a time we installed the signal system shown in the figure.

The signals consist of metal boxes, each containing a lamp behind a translucent front. These boxes are numbered according to the aisles and arranged in groups of three, one lamp for each aisle. A group of these lamps is placed in each aisle where the lamps can be seen easily. A switch in each aisle is connected to light the lamp in each group corresponding to the aisle number. For example, when the switch in No. 1 aisle is closed No. 1 lamp in each group is lighted.

Before blowing down a boiler, the operator glances at the indicator. If it shows clear he closes the switch in his aisle, say No. 2, and a lamp in each group lights to show the other operators that a boiler on No. 2 aisle is being blown down. After blowing down, the switch is opened to signal all clear. If, when a boiler on No. 3 aisle is to be blown down and a signal shows that one on another aisle is being worked on, No. 3 holds up until the signals show clear.

Gorgas, Ala. S H COLEMAN



RESULTS AT FACTORY 4

Near "Tops" for Small Plant

Plain garden-variety power house of George E Keith Co, Middleboro, Mass., lives up to expectations—27 lb of water per kwhr for a 13.5x22-in. 4-valve engine and 75% efficiency for handfired 72x18 hrt boilers

POWER *for March 1939 told, with pictures, working drawings, and test results, the story of a small plant. In equipment and layout it was in no way out of the ordinary. It was simple and inexpensive, without gadgets. But its engineers knew that a simple small plant can be really efficient if care and thought go into all the details of building and operation. They put "big-plant" engineering pains into their small plant and the careful tests they ran after operation started showed that their trouble paid. Now, more than a year later, H A F Campbell, Plant Engineer, writes to tell* POWER *editors and readers how the picture looks today. We say it looks good and think you'll agree. With slight condensation, Mr Campbell's letter follows:*

The enclosed table gives the power-house morning operations for August 12, 13, 14, and 15, 1940, at our Factory No. 4, Middleboro, Mass. Would not your readers be interested to note how this small plant, after two years, is operating today? I hope you may find space enough to publish this data sheet, as is, together with a few comments.

Fitchburg Engine 13½"x22" — Power-House Record 7a.m. to 12 noon = 5 Hrs. — Geo E Keith Co
Piston Valve 200 R P M — 4v Throttle Pres 163 lbs — #4 Middleboro, Mass.
Westinghouse Generator 150 K W — " dryer heat 70° —
" Exciter 7 K W — " Cyl. Back Pres. 4½ lbs — Coal Fuel — Aug. 20, 1940

Date	Coal				Water @ 10½ lbs Evap			K W				Water		Coal	
	Total 7am. to 12 5 hrs	Per hour			Total per hr	Machine Line	To Engine	Generator	Exciter	Total	Cyl HP	per Cyl HP	per K W H	per Cyl HP	per K W H
		Total	Machine Line	To Engine											
Aug. 12 1940	2800 lb	760 lb	180 lb	380 lb	5900 lb	1900 lb	4000 lb	135	5	140	204	19.6 lb	28.5 lb	1.9 lb	2.7 lb
" 13	2400	480	150	330	5000	1600	3400	140	5	145	210	16	23.5	1.6	2.25
" 14	2600	520	150	370	5500	1600	3900	135	5	140	204	19	28	1.8	2.64
" 15	2600	520	150	370	5500	1600	3900	135	5	140	204	19	28	1.8	2.64
Averages	2600 lb			360 lb	5500 lb 183 Boiler HP		3800 lb					18.2 lb	27	1.77 lb	2.56

Engine & Gen Mech Eff = 91%
Overall Power Factor = 90%
Boiler 72"-18-ft tubes H R T
Flue Gas Temp 400 F
CO_2 12% to 13%
Feed Water Temp 218 F
Evaporation 10½ lb
from at 212° 11.4 lb
Boiler Eff 75%
Nut + Slack Coal 14600 B T U

The above Results are with Coal Fuel and with 4½ lb Cyl Back Pres.
With Oil Fuel and Atmospheric Exhaust the results would be about 6% lower
i.e. Water per Cyl H P = 17½ lb
" " K W H = 25½ lb

Results Talk

All will agree that with any given types of prime-mover or boiler and set of steam conditions, it is wishful thinking (or figuring) to expect to get more than certain economies. The enclosed results, under *actual* daily operating conditions, show a 200-hp engine and a 72-in. hrt boiler operating right up around the best economies that the laws of steam engineering will allow. This might be considered news because:

1. This is just a plain and inexpensive plant.
2. The figures given are correct.
3. The results are very good indeed.

No turbine-generator of the same size comes within 25% of these results. A uniflow engine might just about equal them, under daily operating conditions. (This is a counterflow 4-valve engine—see POWER, March 1939 for details—Ed). Results of boiler operation show up well for handfiring, I believe.

The point is just this: with our setup and conditions, we should get these efficiencies and we do. I believe that you will have to refer to text books or handbooks, which quote the best on record, to find daily operating results much better than these.

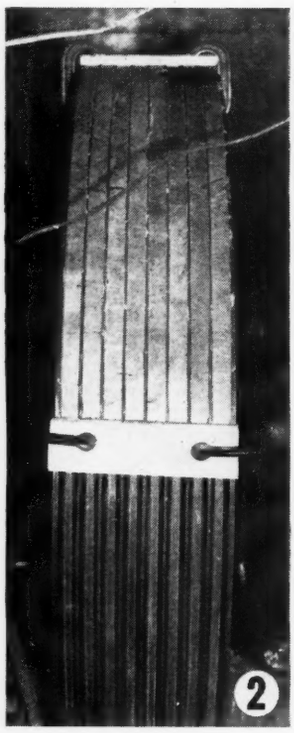
We have had no troubles of any kind (chalk up a score for simple, rugged design—Ed). The plant operates day after day, turning out kwhrs and process steam, and keeps right down to these figures all the time. As always we keep our records and figure results with care. Nevertheless, I am now quite frank to admit that in the MIT tests of 1937–38 we missed one or two points, and to our disadvantage.

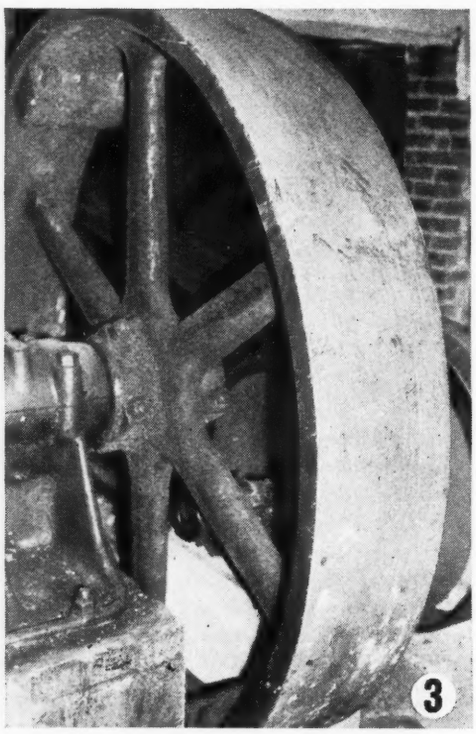
Care and trouble usually show the George E Keith Co dollar savings but what is beyond any dollar valuation is the personal satisfaction of a job pretty well done.—H A F CAMPBELL, *Plant Engineer, George E Keith Co.*

Turbine-Oil Pressure

IF TURBINE-OIL PRESSURE is carried too high, the bearings are likely to be oversupplied and the oil may be sprayed from the ends in thin sheets against the housings and thus be atomized. If the bearing seals are worn or ineffective, considerable oil will be lost. Water-seal glands are not effective at slow speed; and, if oil pressure is not controlled carefully when stopping and starting, oil is likely to leak past the seals into the gland drains. Adequate return pipes prevent the bearings from becoming vaporbound, and atomized oil will drain readily to the reservoir. Oil leakage and atomization create an unsightly appearance and cause slippery floors, added fire hazard, and increased oil consumption.—*Bulletin of Virginia Polytechnic Institute, Vol 33, No. 14, August, 1940.*

PRACTICAL AIDS TO OPERATION





V-Sheave Changed to Flat Pulley

IN A MANUFACTURING PLANT an ammonia compressor was driven by an electric motor through a short-center multiple-V-belt. This drive had operated for several years at the time a diesel-engine was installed. The length of the drive between engine and compressor was too long for a V-belt, so a change was made to a flat leather belt. To save a large part of the cost of a flat-rim flywheel for the compressor it was decided to fill the grooves in the large V-belt sheave so that the flat belt could run on it.

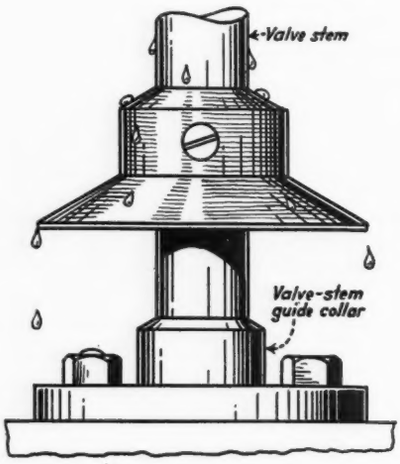
We did this by making leather V-strips that just filled the grooves and of a length equal to the circumference of the flywheel. We covered the surface of the grooves with a waterproof cement, see Fig. 1, and then the V-sections were forced tightly into place by clamps, Fig. 2. When this work was completed the ends of the sections were fastened together by a tapered cemented lapped joint to make sure that they would not work loose and come out of the grooves. We covered the surface of the flywheel with a coat of pulley-surfacing compound; the finished job is shown in Fig. 3 which looks very much like a cast flywheel.

New York, N. Y. L H SKOUGOR
Engineer, Am Leather Belting Assn

Keep Condensate out of Crankcase

WE HAD TROUBLE with condensate from the valve stem of a vertical engine getting into the crankcase lubricating oil. This water ran down the valve stem onto the guide collar on the crankcase and into the lubricating oil. To prevent this I made a tight-fitting guard to go onto the valve stem as in the figure. Water running down the stem is diverted away from its lower end and prevented from reaching the crankcase through the valve-stem guide.

New York, N. Y. S M ELONKA



Vibrating Cleaner Deslags Boiler Tubes

SLAG FORMATION on the external surfaces of water tubes is frequently a real problem with high-capacity boilers, especially when burning some kinds of pulverized coal. How long a boiler may remain on the line is often determined by the amount of slag that builds up on the tubes exposed to radiant heat. When this becomes so great that draft is impeded, a shut down for cleaning is often necessary. This slag, somewhat plastic and sticky at operating temperatures, becomes dry and more or less brittle

when cooled and may be quite difficult to remove from the tubes.

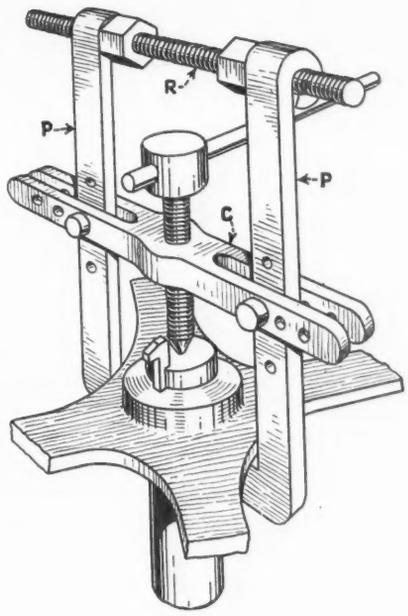
There are not too many practical methods of removing this slag. Quite often the slagged tubes are 30 or 40 ft above the furnace floor, and while a ladder may reach, it may be quite dangerous for a workman to attempt to knock off the slag at this height. Then, too, it is possible to construct staging. But for the single job of slag removal, staging may prove too costly and there may not be available time to permit its construction.

One method used in a plant having several watertube boilers was to provide the workmen with long poles. The men would stand on the furnace floor and jar the tubes with the end of these poles, a very dangerous practice. In our plant we tried a vibrator-type tube cleaner, such as used for descaling the water-side of fire-tube boilers, with a high degree of success. It is a comparatively simple matter to remove the tube caps from the ends of the tubes exposed to radiant heat, and run the cleaner through them. This method is both safe and effective.

Cleveland, Ohio A G WIGGINS

A Lock-on Pulley Puller

SEVERAL TYPES OF PULLEY and gear pullers are in use, but I have found the design shown in the figure to have many advantages. It was made in our shop, is adjustable as to size of pulley or gear, and can be fastened tightly in place before starting the pulling operation. Holes in the pull bars *P* and crosshead *C* permit a wide range of adjustment. After the pull bars are in place on the pulley or gear hub they are locked there by the nuts on the threader rod *R*. The jack screw in crosshead *C* is tightened against the shaft end to remove the pulley. Construction of this puller is simple and requires very little machine work.



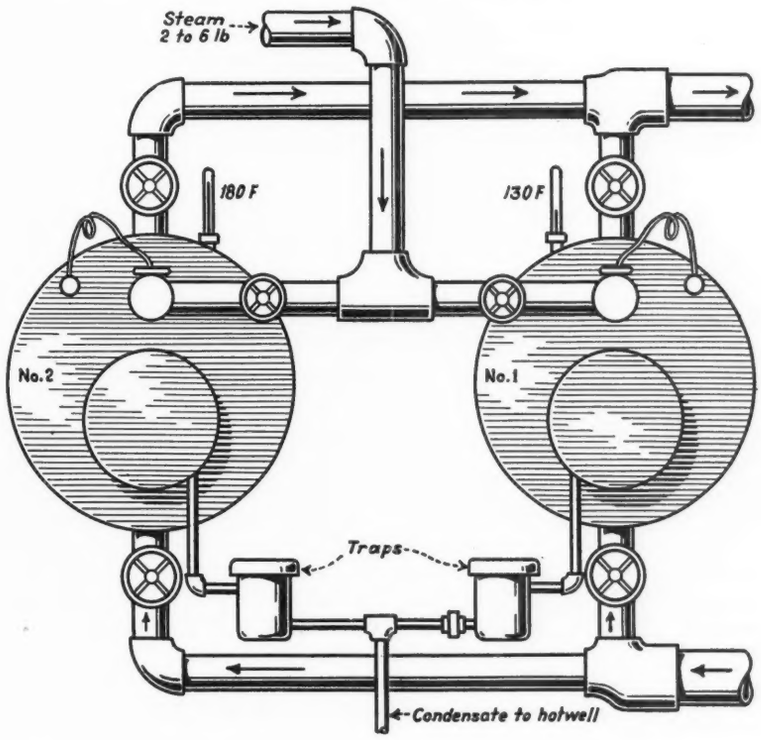
Penacock, N. H. C H WILLEY

Faulty Valve Causes Low Water Temperature

A FAULTY OPERATING VALVE may cause a lot of trouble. This proved to be true of two water heaters connected as in the figure. No. 1 heater operated all right except during peak demands when its water temperature dropped to 150 and sometimes to 130 F. The temperature of No. 2 heater remained constant around 180 F at all times, where it should be.

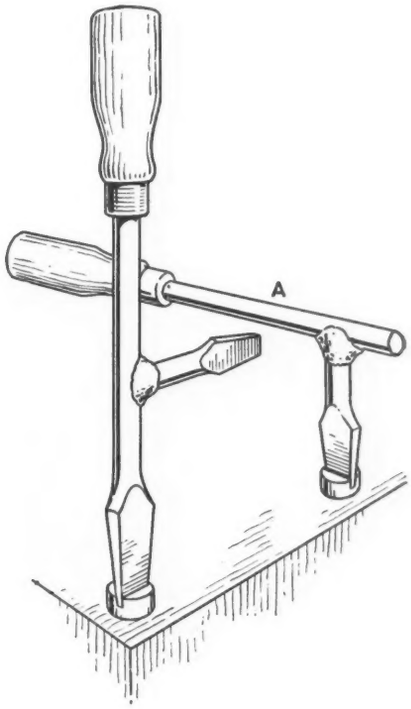
After trying several things to correct the trouble, including opening up No. 1 heater, we found the cause. While we had No. 1 heater open it was discovered that when water was drawn from No. 2 the pressure drop across it was about 30 lb. This indicated a restriction in the water circuit of the heater. That night we shut down both heaters and found that the outlet gate valve of No. 2 heater was only partly opened, the stem having become detached from the gate.

Marissa, Ill. GEORGE BLUM



High-Powered Screw-Driver

MANY TIMES I wished for more power on a screw-driver to start a stubborn screw, before I fell upon the idea shown in the figure. On the shank of a regular heavy screw-driver is welded a stub screw end of another driver. This arrangement gives the regular straight



screw drive for fast, easy-going screws. For the tough one, use the short section with the regular driver acting as a lever for more power, as at *A*. If the regular screw-driver has to be used on a stubborn screw, then it can be turned with a wrench applied at the tee.

Penacock, N. H. C H WILLEY

This Grease Dispenser Works Well

THOSE RESPONSIBLE for maintaining heavy machinery know the disagreeable and wasteful process of handling bulk grease and refilling hand-type grease guns. One mechanic of a large company, with the aid of a welder, built the grease dispenser shown in the photo from old scrap and discarded material.

He cut the bottom out of an empty 30-gal oil drum and welded a sheet metal cone in its place. An old hand gear pump was then connected to a pipe nipple welded to the bottom end of the cone. A goose-neck of ½-in. pipe put the pump discharge in a convenient place. Discarded lengths of pipe making up the legs and bracing were welded to the drum assembly.

An entire pail or drum of grease can be emptied into the dispenser at one time. By simply turning the small crank, any desired quantity can be pumped out without waste. A particular advantage lies in being able to refill grease guns by inserting the goose-neck to the bottom of the gun chamber and gradually lowering the gun as the grease is pumped in. This eliminates troublesome air-pockets usually trapped in when filling with a paddle or ladle.

Alhambra, Calif. G. M. WILSON

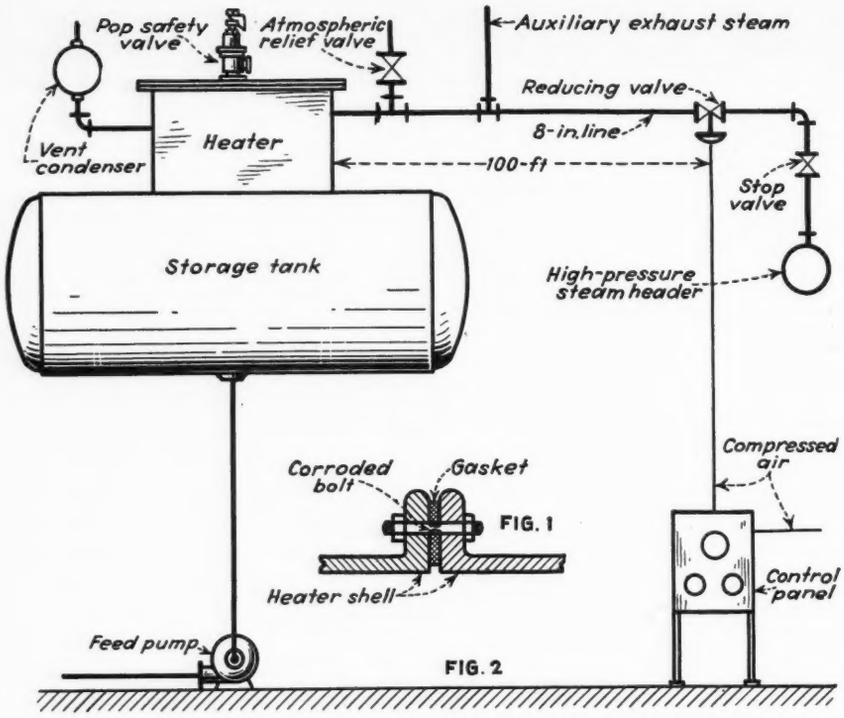


FIG. 1

FIG. 2

Watch Low-Pressure Steam Equipment

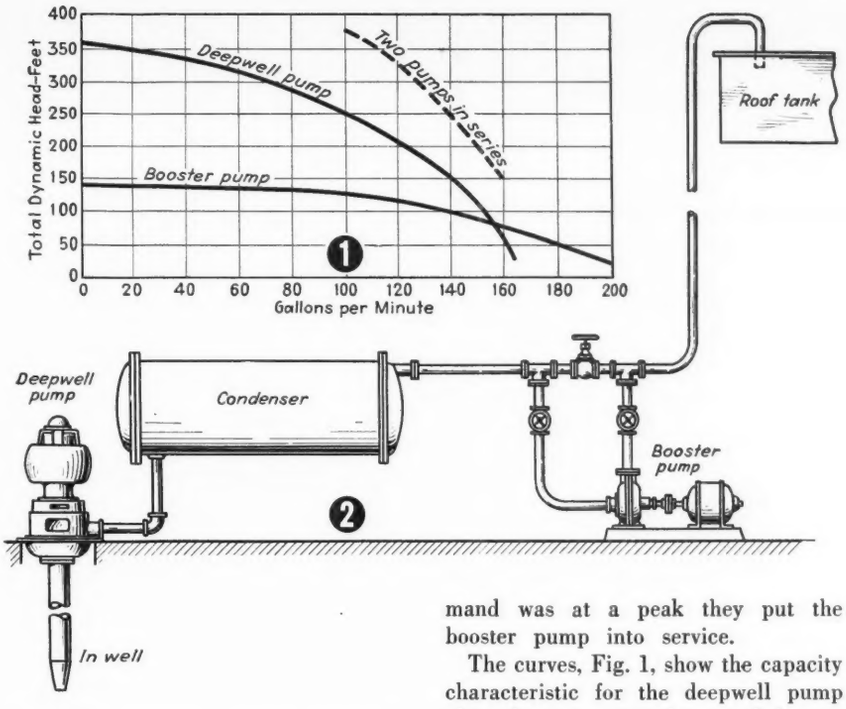
LOW-PRESSURE WATER HEATERS are a potential explosion hazard unless properly operated, as the following experiences show. An open-type feed-water heater, supplied with steam from the exhaust of a steam turbine, operated against a back pressure of 8 lb per sq in. A back-pressure relief valve of adequate size was set to blow at 10 lb per sq in., and gases from the heater were vented to atmosphere through a small line, throttled by a valve to prevent waste of steam. The heater was good for an operating pressure of at least 15 lb per sq in. After 15 years service the heater exploded and tore a large hole through a brick building wall.

An investigation revealed that the failure was due to the shell sections separating at the flanged bolted connections, Fig. 1, and not to over pressure. Leakage through these joints had reduced the diameter of the bolts by corrosion so that they failed with normal pressure in the heater.

In another plant a deaerating feed-water heater failed due to conditions produced by operating practice. This heater was supplied by exhaust steam from auxiliaries, with a live steam makeup line, Fig. 2. A compressed-air-loaded, automatic pressure-reducing valve in the 8-in. line near the ceiling of the boiler room was controlled from a panel board on the operating floor. An atmospheric relief valve of ample size, located on the 8-in. line close to the heater, was set at 8 lb per sq in. In addition to the relief valve, a small pop valve on the heater was set at 15 lb.

Because the manually operated stop valve on the high-pressure line was in a remote location, the system was shut down by closing the reducing valve from the operating panel. When starting up the reducing valve was opened with the compressed-air controlled on the panel. This valve opened rather quickly and the sudden steam flow through the 100 ft of cold 8-in. pipe produced a large volume of condensate that rushed into the heater and caused it to fail because of a severe water hammer.

Now when shutting down the system, the manually controlled stop valve is first closed. The automatic reducing valve is then unloaded, and all drains and trap bypass valves are opened. When starting, the automatic reducing valve is opened from the operating panel and a check made to be sure that it is wide open. The manually operated stop valve is then cracked open and



kept in this position to permit restricted flow of steam until the line warms up thoroughly. When drainage has been completed and steam starts blowing through the drips and trap bypass lines, the stop valve is opened slowly. Drips and bypass valves are then closed.

These and other accidents that have occurred emphasize the need of care in the operation of water heaters and other low-pressure steam equipment.

Chicago, Ill. R O Billings

Booster Pump Raises Head and Capacity

The solution of a pumping problem in a large dairy may be of interest since necessity for increasing the water supply may occur in other plants. This dairy had a deepwell turbine pump, rated 100 gpm against 250-ft total head. Water level in the well during pumping was approximately 100 ft below the floor. Balance of the pumping head consisted of friction through a condenser and piping plus a vertical static discharge head of 90-ft to the roof tank, Fig. 2.

Due to an increase in plant size and the necessity for improving refrigeration efficiency, water flow had to be increased to 140 gpm. This was done, without any change in the deepwell pump, by installing a booster pump as shown. During normal daytime operation when the demand was low, they closed the bypass valves and let the turbine pump discharge directly to the roof tanks. When the refrigeration demand was at a peak they put the booster pump into service.

The curves, Fig. 1, show the capacity characteristic for the deepwell pump alone, booster pump alone, and the two pumps operated in series. The turbine pump delivers 100 gpm operated alone against the 250-ft head. When operating through the bypass line in series with the booster pump, the turbine pump discharges against 150-ft head only and delivers 140 gpm to the booster pump which takes care of 100-ft head from floor level to the roof tank. The booster pump was selected for a capacity of 140 gpm against 100-ft head; therefore, the two pumps in series deliver the 140 gpm against the 250-ft head as required.

This method was a comparatively inexpensive way of increasing the capacity of the plant, and within limits can be applied to any other installation of an existing centrifugal-pump job.

New York, N.Y. Frank A. Kristal

Cleans Glass Tubes with Acid Solution

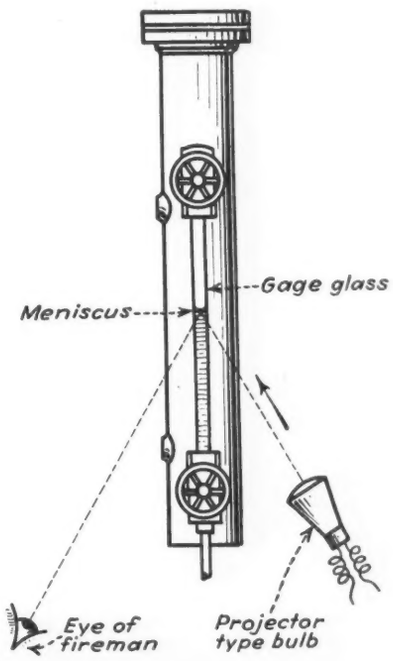
In our plant we have quite a number of glass tubes that require thorough cleaning. To do the job we use a solution of either hydrofluoric or nitric acid in water in which the tubes are soaked for about 20 minutes. We have found that a 5% solution of hydrofluoric acid does the best job, but care must be taken not to have the solution too strong or soak the tubes too long. After the tubes are removed from the acid solution we wash them thoroughly in running water and then blow out with compressed air taken through a filter to insure proper cleanliness.

London, England W L Warner

More Light on the Gage Glass

Gage glasses are generally illuminated with little attention given to making the light most effective. After a little experimenting I was surprised to find that the lamp should be placed below the water level, as in the diagram, so that the light rays are projected upward against the meniscus. The meniscus then acts as a lens to direct the light down to the observer's eye, as indicated. In fact, a bright band of light (see photo) visible for a long distance, appears to float on the surface of the water in the gage glass. Best results are obtained with a reflector type bulb. This little trick is another example of how a simple change may make considerable improvement in the operation of a piece of equipment.

Battle Creek, Mich. C A Van Deursen



ARGUMENT CORNER

Somebody Got His Figures Twisted

I HAVE JUST LOOKED OVER POWER for October, 1940. The article about the New Weatherford, Texas, diesel plant, page 130, arrested my attention and I am certain there is a typographical error or else some one got his figures twisted, because "there's something screwy about it."

The photograph shows three engines and the sizes as given are: 6 cyl, 14 x 17 in., and driving 300-kw alternators at 1750 rpm. The picture shows the alternators direct coupled and that means that the engines run at the same speed. Let me say now I don't believe it can happen here!

I don't believe the engines would hang together or stay in the house running at that speed. Furthermore, this would give a piston speed of 17 in. x 2 x 1750 ÷ 12 in. or 4958.3 ft. per min. Again, furthermore, if 1750 is correct and there are four poles in the field, then the frequency would be 58.3 cycles, which is not standard anywhere.

Also, judging from the photo, I would say that the exciter drive looks to be about a 5-to-1 step-up ratio in pulley diameters. If so, this means that the exciter would run at the unheard of speed of 8750 rpm. Maybe if I looked further, I could find some more arguments to support my contention that there is something screwy somewhere, but I believe I have said enough for the time being.

Clarksdale, Ariz. FRANK AVIS

[TO EAGLE-EYED READER Frank Avis and to operators of the Weatherford, Texas, diesel plant, our regrets for giving them nervous prostration by running these engines at 1750 rpm. There *was* a typographical error; the 1750 rpm refers to the V-belted exciters rather than to the engine. Actually, these three diesels operate at 300 rpm.—Ed]

A Point in Soldering Cable Lugs

ON PAGE 116 of September POWER I note an instructive and complete article covering the proper soldering of a cable lug to wire or cable. In addition to the instruction given, it is very important to use a lug not over 1/16 in. larger in inside diameter than the diameter of wire or cable.

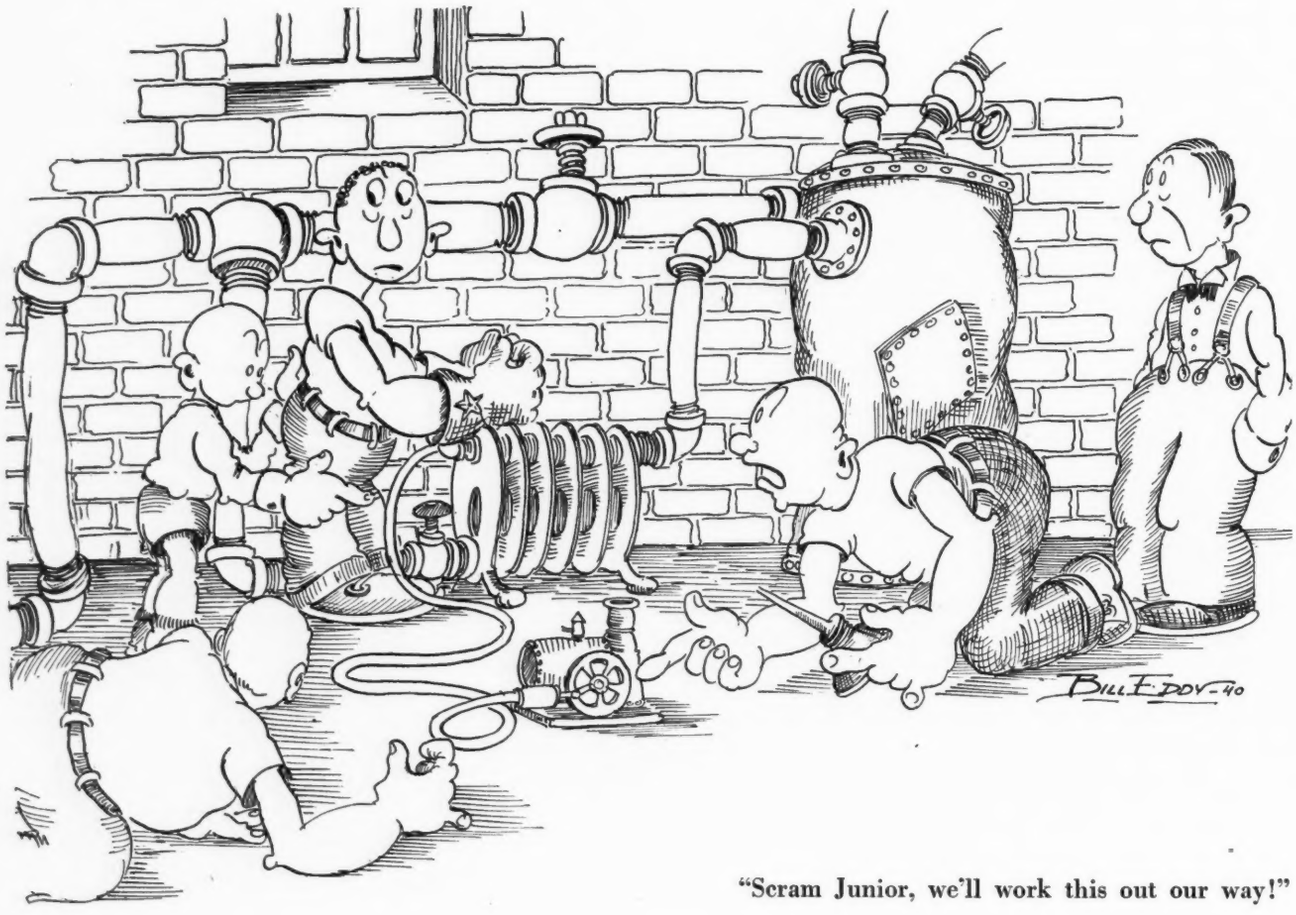
After a mechanic has become thoroughly proficient in the work, it is an excellent idea to use only mechanical lugs, preferably compression type.

San Francisco, Calif. M A DELEW

Correction

ON PAGE 136, November POWER, under the heading "Wind Power Plant for the Green Mountains", it is stated that energy to be developed will be delivered into the Green Mountain Power Corp system. This should be the Central Vermont Public Service Corp system.

Augusta, Maine FRANK H MASON
Chief Engineer,
Nepsco Services, Inc



"Scram Junior, we'll work this out our way!"

READERS' PROBLEMS

Questions from Our Readers

More Hp from Steam Engine

Question 1

WE HAVE *a Ball & Wood tandem-compound, 4-valve engine direct-connected to a 200-rpm, 200-kva, 440-volt, 3-phase generator. The high-pressure piston is 17$\frac{11}{32}$ in. diameter, the low-pressure piston is 34$\frac{17}{64}$ in., and the stroke is 18 in. The engine is about 35 years old but in good condition. This unit has a center crank with outboard bearing. A wheel governor controls steam valves on both cylinders, through a single rod, and a single eccentric (adjustable by hand) operates exhaust valves on both cylinders. At 115 lb throttle and 8 lb backpressure the engine develops about 102 hp. How can we increase the output?*

The early cut-off in the low-pressure cylinder causes the expansion line to go below receiver pressure and the backpressure causes compression to be too high, so that this cylinder develops practically no useful hp. The construction of the engine is such that it is impossible to add a third eccentric and rocker arms to handle the low-pressure steam valves. It has been suggested that we equip the engine with a throttling governor and set the present wheel governor at a predetermined cut-off point. Economy is no object, and the existing regulator can take care of voltage—RMD

How Reduce Flyash?

Question 2

CAN POWER READERS *pass along some simple, practical method of reducing flyash when using spreader stokers under water-tube and hrt boilers? Our units are reasonably high set and have sufficient combustion volume. The boilers are equipped with combustion control and draft under and over the fire has been reduced to a minimum.*—KB

SUITABLE answers from readers will be paid for if space is available for publication. Practical drawings or photographs will command additional pay.

Worn Diesel Piston

Answers to Oct Question 1

The Question

ON PULLING A PISTON *of our 4-cycle, 250-rpm, 8-cyl, 1000-hp mechanical-injection diesel, we found that the piston was worn oval about 0.015 in. on the thrust side, and all the rings were worn in a similar manner. As a matter of fact, the rings were worn to about half their original depth at that point. The liner was in good condition, showing no scores and only normal wear. We installed a new piston and ran for 3 hours. The wrist pin then got hot, causing the piston to score the liner.*

Pistons are lubricated from an outside lubricator, which was working OK when the scoring occurred. When running the engine now, we hear a noise from that cylinder, which, we assume, is a piston slap, as all the bearings have been checked. This is the second time we have changed a piston and the second time this has happened. The engine is only 11 months old. The pistons were checked before installation and found to be at the required dimensions. Is it good policy to have the old liners rebored and oversize pistons installed? Can some POWER *reader suggest a cause and remedy for the trouble?*—RRS

Check the Wristpin

FROM RRS'S DESCRIPTION of the troubles encountered and the fact that they only occur in one cylinder, plus the fact that the wristpin heated after being fitted, would put this latter member under suspicion, and definitely so if the wristpin is fitted into two straight bores of different diameters. While the pin must be fit snugly to prevent pounding during pressure reversals in the 4-cycle engine, the tendency is to go to extremes and drive the pin too tight.

The result, in some cases, is forcing the pin out of round. This would account for the liner being eccentric while the piston and rings are oval. The reason the liner scored after the second pin was put in indicates more tightening of the pin than in fitting it to the previous piston. This can be overcome by boring the holes in the piston for a taper, making a new pin machined so the extremes will fit the tapered piston holes while the bearing section is machined for the bearings. This is standard construction in many engines and can be easily adapted to any trunk-piston type; the taper fit will lessen the chances of distorting roundness of the piston.

Galt, Ontario H PARKINSON

A Problem of Alignment

RRS SEEMS TO BE UP AGAINST a problem of alignment. If the pistons of any multi-cylinder engine are in true alignment with their wristpins and cranks, and all cranks are centrally positioned between the webs, there should be no uneven strain on any particular piston to cause it to wear on the lateral or thrust side. It would seem that the piston is being required to absorb part of the load thrust.

According to RRS, "all the bearings have been checked," but it is obvious he means the crank and wristpin clearances are not great enough to cause the "noise from that cylinder, which, we assume, is a piston slap." But has he checked the vertical alignment of piston, wristpin and crank as well as the alignment in relation to the other pistons?

Perhaps the wristpin or crank brasses are not truly fitted, i.e., they may be down at one side, causing the piston to lay over hard when the bearings are assembled. Or, there may be a kink in either piston or connecting rods affecting the alignment in a like manner. This is reasonable if we examine the statements, "The liner was in good condition showing no scores and only normal wear," when the piston was pulled the first time. And, again, when the new piston was installed and the engine run, "The wristpin then got hot, causing the piston to score the liner."

This last seems to be the key. The hot wristpin should not cause the piston to score unless it is out of alignment. It stands to reason that the piston pressing hard against the wearing side made the wristpin run hot.

A practical way to check alignment is to disconnect the crankpin brasses and turn the crankpin to bottom center position. Then drop the piston and connecting-rod assembly to the bottom of the stroke and center-punch the middle of the connecting-rod foot. Make certain at the same time that other crank bearings are centrally positioned between the webs. Now, using a pin gage, check the distance from the center-punch mark to a fixed point at either side, also center-punching these points.

Move the piston and connecting rod to top center and the crankpin as well. If, from the fixed points, there is no variation in distance to the center-punch marks at top or bottom center, the wristpin is true. Then all that remains is to check the crank in the same way.

If the connecting rod has to be forced into position when either crank or wristpin bearings are being assembled, it is not lined up properly. On short-connected engines, such as this diesel appears to be, a small difference in vertical alignment, say $\frac{1}{32}$ in., at the crank may be enough to cause piston wear, or even a scored liner.

New York, N. Y. WM S DOWNS

Expansion Gasket Missing?

I SUGGEST A CHECK to see if all of the expansion gaskets between cylinder units are OK and accounted for. If one of these gaskets is left out, normal expansion of the cylinder will be blocked and the bore of the cylinder will be distorted by the strain. As the piston is of softer metal than the liner, the piston will be worn oval.

The only cure is to insert an expansion gasket in its proper place to relieve strain on the cylinder.

W Lafayette, Ind. W J Ross

Check Cylinder Liner and Wristpin

IF WEAR SHOWS ON THE PISTON and the rings are badly worn, the liner is also probably worn or "egg shaped." RRS makes no mention of this, but the liner should be carefully checked with inside "mikes". However, the liner is harder than the piston or rings and may be worn less as it runs much cooler.

Heating of the pin might be caused by improper fitting or too little clearance of the piston in the liner. If the liner is worn or distorted, the new piston will seize. The pin must have room to expand lengthwise or it will distort the piston and cause trouble. Fitting a new piston and pin is a very particular and tedious job, and all dimensions and clearances must be exactly right to operate when they reach working heat.

Rebored liners with new pistons are as good as new, but the factory should do the job. Local shops seldom have the proper equipment. On a large engine it is better to use *all* rebored cylinders and new pistons, not just one or two.

Carlsbad, N. M. J E MATKINS

Is Enough Oil Reaching the Piston?

IT MIGHT PAY RRS to remove the oil line from the cylinder and operate the lubricator manually to see if oil is reaching the piston from the orifice. Also, the wristpin should fit loosely enough to be turned by hand in the bearing, to allow for expansion. Seizure of the wristpin, a flat spot on the crank shaft or an improperly fitted bearing will cause the piston to ride against the liner and cause considerable wear on the softer liner material.

Humboldt, Sask. T L PATTERSON

Two Factors Produce Piston Distortion

FROM THE WORDING OF THE QUESTION, cylinder-liner scoring can be caused solely by piston distortion. Two factors combine to produce this condition:

(1) When the wristpin and piston were assembled, the fit between the two must have been too snug. Perhaps the pin was not covered with enough oil before being driven into place.

(2) After installing the piston and operating the engine for awhile, the pin must have become worn and elongated because of insufficient under-piston cooling. Because of the close fit, this elongation increased the piston diameter in line with the pin, so much so that the piston touched the cylinder wall and caused liner scoring.

RRS states that his lubricating apparatus was operating satisfactorily just prior to liner scoring. This may not have been true, but maintaining a specified oil pressure does not always insure sufficient under-piston lubrication. RRS should also check the oil line leading to the underside of the piston to be sure it is not clogged. Particularly the check valve, oil-outlet holes, or spray nozzle should be free of anything that might hinder free passage of oil to the piston and bearing. If this is done and factor (1) observed there should be no further trouble.

New York, N. Y. BRIAN CORRIGAN

Piston Is Doing More Than Its Share of Work

ONE OF THE PRINCIPAL REASONS for the wear RRS reports is that this piston is doing more than its share of work because of a faulty injection nozzle or a wrong fuel setting. This can be determined quickly by putting a pyrometer on the exhaust outlets; the temperatures should not vary more than 25 deg from one cylinder to the next.

Then, too, the pressures in this cylinder may be much more than in the other cylinders. If this is found to be so, then, in most diesels, the connecting rods can be lowered or raised. Lowering the piston decreases the cylinder pressure.

This piston may not be getting enough oil, especially from the line going to the side of the cylinder that the piston thrust is on. The fact that the wristpin on this cylinder got hot in a few hours indicates that there is not enough oil at the wristpin.

If his engine shows some wear on other cylinders, then perhaps RRS is using the wrong oil or else the engine has no air filter. If the diesel has removable sleeves, I recommend renewing them and installing new standard pistons rather than reboring the old liners. Unless the job is done by the factory or by a first-class machine shop, the rebored liners will not give as good service as new pistons and sleeves. Also, cost of a rebore job on oversize pistons will not be much less than new liners and standard pistons.

Bismarck, N. D. LESLIE BRADLEY

Rain Water for Boiler Feed?

Answers to Oct Question 2

The Question

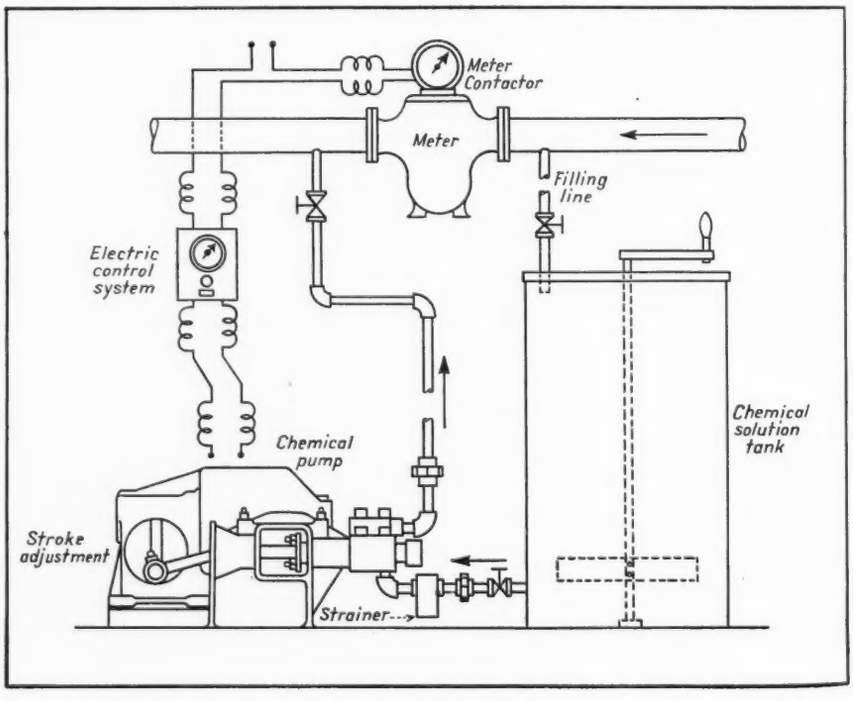
WE ARE LOOKING *for information concerning the advisability of using rainwater collected from the roofs of our buildings as feed for our steam boilers. We have both bent- and straight-tube units ranging in size from 3000 to 5000 sq ft heating surface. Roofs are constructed of slate and metal. Rainwater is conducted through metal downspouts and then through sewer pipe into underground concrete reservoirs. From this storage we propose to draw water for boiler use. Is there any possibility that this wouldn't be suitable?*—JW

How to Treat for CO_2 and Oxygen

SINCE RAINWATER COLLECTED FROM ROOFS contains practically no solid matter, this water cannot produce scale or increase substantially in specific gravity in the boiler. However, rainwater collects some CO_2 and oxygen from the atmosphere; these dissolved gases make water quite corrosive.

If an effective feedwater-heating system is available, these undesirable gases will be quite completely removed before the water reaches the boilers. On the other hand, if J W finds that his feed-heating equipment is not removing these gases, he should treat the water with a trace of alkali, as for example, with phosphate and a little sodium sulphite.

A small conventional chemical pump, see



sketch, can be used to add the necessary alkali and sodium sulphite. Such a pump, with the necessary chemical-solution tank and electrically controlled water meter, will give fully automatic and proportional feeding of the chemicals with very little attention.

Clayton, N. J. S F ALLING

Problem of Collection

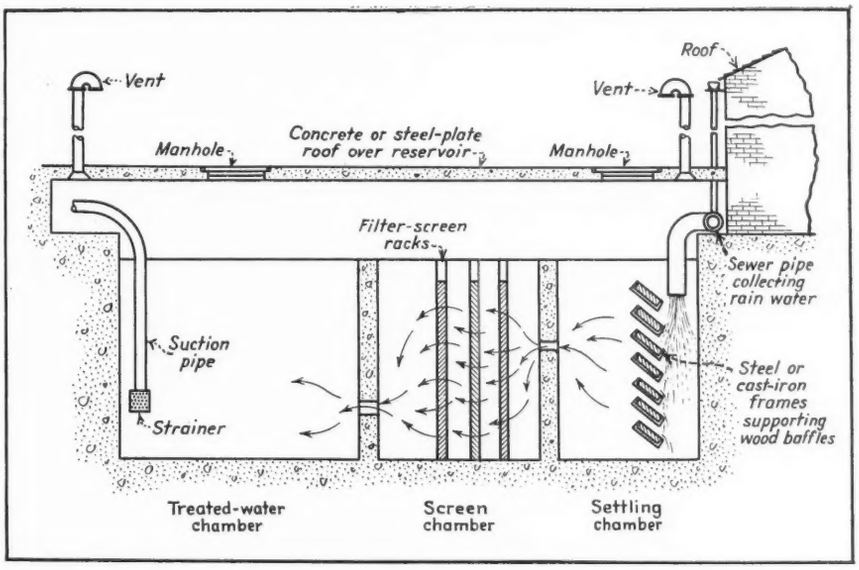
ALTHOUGH THERE MAY BE some question as to the suitability of rainwater for boiler feed, to my mind the principal problem is the practicability of collecting and storing it. The size of the plant is not given, but since there are several units of 300 and 500 boiler-hp capacity, for estimating purposes we can assume a maximum water consumption of 20,000,000 lb per month (at 100% makeup) required by two 500-hp boilers operating 24 hrs per day at normal rating.

In some months, there is practically no rain at all and in other months most of the rain comes down in a single day. In order to get along with as little other water as possible, the capacity of the reservoir should equal one month's supply. This means more than 300,000 cu ft, or a reservoir about 180 ft square and 10 ft deep. This practically is a pond, and it is questionable whether water stored in an open pond can still be classified as rainwater. Cut this capacity figure down to one tenth and assume that the plant requires less than 20,000,000 lb per month—you still have something that appears impractical.

Now consider how the water is to be collected. Three in. of rainfall per month is a good average. 20,000,000 lb is 320,000 cu ft. If 90% of the rain is collected, a 3-in. rainfall will require 1,440,000 sq ft. If the size of the average building is 100x100 ft, then this company must have more than 100 buildings to collect the rain.

Thus, the collection of rainwater doesn't look practical, if the boiler feed is 100% makeup or nearly so. However, if JW's plant is condensing, with say 5% makeup, and if the locality is favored with frequent rains, he may be able to store the water in a concrete reservoir about 40 x 40 x 10 ft.

Oak Park, Ill. N T PEF



3-Compartment Reservoir

RAINWATER AS BOILER FEED has been found satisfactory in many cases, but only in a few has it been possible to operate without chemical treatment before use.

Purity of rainwater depends on environment; if the atmosphere is polluted with gases and soot particles from industrial plants, a qualified feedwater expert should be consulted. In industrial areas, rain practically washes the air free of gases and soot, and picks up more from the roof top, before it arrives at the reservoir.

The reservoir should have two or three compartments, the first to be used as a settling chamber, where a coagulant can precipitate the solids in the water. The second chamber should have a screen or filtering device. The third compartment serves as a reservoir from which to draw off water to the heater or economizer, thence to the boiler.

Grand Rapids, Mich. JOHN M GORRIE

There Are Many Ways of Treating Properly

FROM THE STANDPOINT of mineral impurities, rainwater is about as pure a water as can be obtained, and its action, as far as possible scale formation is concerned, is negligible. There is, of course, some possibility of suspended dirt and other foreign matter being washed from the roofs, but most of this will settle out in sort of a retaining tank.

While such water would not cause any serious problem in the way of scale formation, it would have to be watched very closely and treated to prevent corrosion and pitting, due to dissolved gases. Modern practice, however, provides many methods of destroying, absorbing, or changing these gases into harmless form. Under proper treatment, rainwater, if enough is available, should be a very satisfactory feedwater.

Winnetka, Ill. DUDLEY K FRENCH

May Cause Corrosion

J W WILL FIND that using untreated rainwater may cause serious corrosion in his boiler. It is true that the water will be soft, but he will find it high in oxygen, and if his plant is in an industrial area, he will find the water high in dissolved CO_2. It will be necessary to treat for the removal of both these gases.

We suggest that the pH alkalinity of the boiler water be kept between 10.5 and 11.2 as further insurance against corrosion.

Cleveland, Ohio H W HANNAH

Don't Use It Except As a Last Resort

WHILE WE USUALLY THINK of rain as Nature's purest form of water, there is a general feeling among boiler-water chemists that rainwater should be used as boiler feed only as a last resort.

When rain falls through the atmosphere, it absorbs such gases as CO_2, SO_2, hydrogen sulphide, and, of course, oxygen. In industrial sections, SO_2 and sulphuric acid, and often other acids, are discharged from stacks in vapor form. Nitrous and nitric acids, always present to some degree in the air, are formed during lightning discharges and also absorbed by rain.

Rainwater is definitely corrosive (its pH ranges from 4 to 6). Today, experts advise using boiler feed that is alkaline and free from dissolved oxygen or CO_2, if one is to expect any measure of freedom from pitting or general corrosion. It would thus be necessary to treat rainwater and deaerate it. In many cases this would be as expensive as treating other available waters.

The uncertainty of reliable supply, the cost of collection and of chemical treatment, and the practical certainty of corrosion unless proper chemical treatment is used, make rainwater for boiler feed definitely inadvisable except as a last resort.

Staten Island, N. Y. L A ELLISON

Rainwater Needs Chemical Treatment

RAINWATER is essentially distilled water which, in falling through the air, has picked up and assimilated gases such as oxygen, CO_2, etc. It is, however, practically free from mineral salts. The extreme softness of rain water plus the dissolved oxygen and acidity tend to make it corrosive. However, with proper treatment this water can be used.

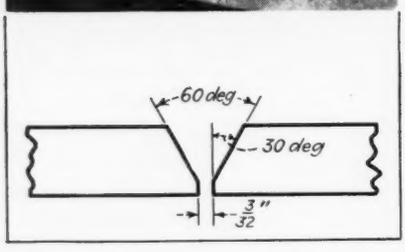
Proper treatment consists of raising the pH value and alkalinity; a pH of 9.6 is considered non-corrosive. Alkaline salts, such as caustic soda, soda ash and trisodium phosphate, are generally used for this purpose. Modern high-pressure plants usually find it necessary to install deaerators to remove dissolved oxygen, but medium-sized plants can get along with an open feedwater heater. The heater will drive off most of the oxygen, if properly vented. Temperature of the feed heater should be at least 210 F. If not enough exhaust steam is available, the deficiency can be made up by bleeding high-pressure steam into the heater.

(Continued on page 134)

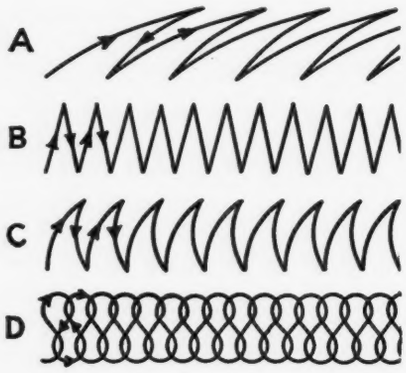
HOW TO MAKE A VEE-BUTT WELD

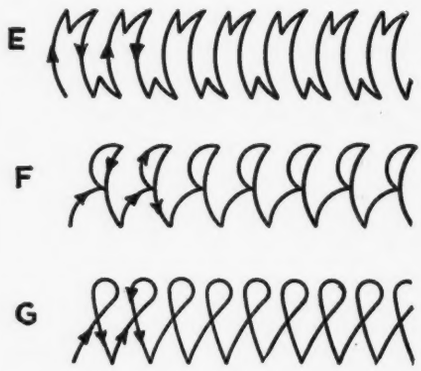
(Prepared with the cooperation of the Lincoln Electric Co. Photos posed by POWER *in Lincoln's New York demonstration room)*

▶ THE TWO PRECEDING ARTICLES showed: "How to Strike an Arc and Run a Bead", and, "How to Make a Simple Butt Weld." The $\frac{3}{16}$-in. plates of the last exercise were butt-welded without beveling, and the electrode was moved down the center of the seam in a straight line. Plates $\frac{1}{4}$ in. or thicker must be beveled before butt welding. The wide Vee thus produced generally requires at least two layers of welding bead. The second bead, being wide, requires a "weaving" motion of the electrode.



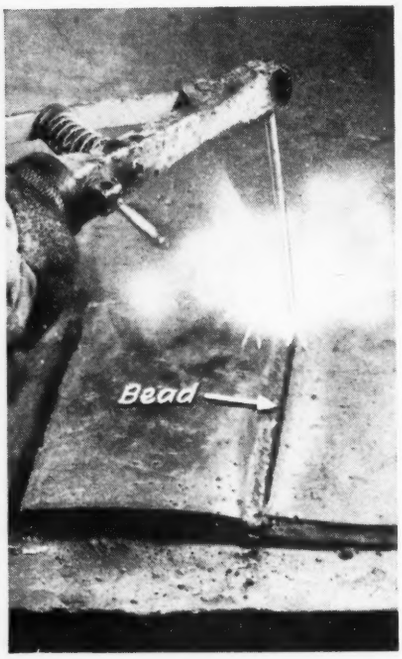
2 **Bevel two plates (Say ½ in.) as shown in the skeetch and lay them on the table with the lower edges evenly separated by 3/32 to ⅛ in. Tack weld at both ends and then check spacing**

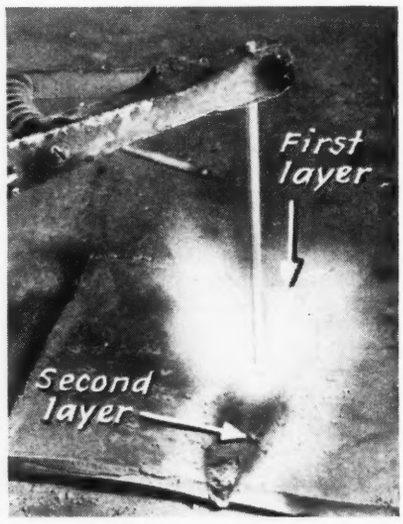




1 **Sketches show seven "weaving" patterns, each depositing a wide, uniform layer of weld metal. Such woven bands are used in building up surfaces, bridging wide gaps and for many other purposes. Weave *C* is most common. Weaves *A* and *B* give much the same effect. Weaves *D* and *E* give the arc more time at the outer edges if more heat is required there. Weaves *F* and *G* are "one-sided", give more heat on one side than on the other. This is necessary where there is more metal on one side than on the other. Practice all these weaves on the flat surface of a metal plate before proceeding with the butt weld to be described. Experience will indicate which weave is best for a given job. While the hand moves as shown in the sketches, the patterns pictured will not show on the resulting welded surface. This should be smooth and even, except for the normal evenly spaced ripples. The welded band should be uniform in height and width, free from holes, depressions or spongy places**

3 **Using a ⅛- or 5/32-in. coated rod, run a straight bead down the bottom of the Vee, without weaving. Be sure current and speed of movement of rod are such that *weld penetrates to bottom of Vee* all along. When this bead is correctly completed (inspect under side for penetration and fusion), clean off slag and scale with chisel and wire brush before starting second layer**





4 **Using a weaving motion (pattern *C* is satisfactory), lay the second bead. Control current, motion and speed to give a smooth, uniform weld rising above the level of the plate, but without overhanging or undercutting. Be sure to get complete fusion with the bottom bead and with sides of the Vee**

Note 1: Slice weld with a saw, and inspect for defects (lack of penetration, poor fusion, overlap, undercutting, holes, porosity).
Note 2: The next in this series (No. 4, January POWER*) will show how to make lap and tee welds.*

DAYTIME BLACKOUTS

A Case Where a Valve Menaced Plant Operation

SOLVED WITH PREVENTIVE MAINTENANCE

FROM his window the Superintendent of a chemical processing plant saw the stacks belching smoke that turned day into night. It happened before—just recently.

Suspecting boiler trouble, he became alarmed. "Maybe there's one reason for production delays!" He grabbed a phone. "Why the blackouts, Bill?"

"The forced draft blower is acting up," replied the engineer, "the valve in the steam line's gone out again!"

Only a short time ago this valve was repaired. Yet, again, it was causing irregular boiler operation and fuel waste; in fact, it might have crippled the boiler completely! That's how Preventive Maintenance—the modern way of protecting against trouble by stopping it at the source—entered the case.

The engineer knew that valves shouldn't behave that way. But he wouldn't risk ordinary repair again. And through the Crane Man, R. B. H., he would benefit from Crane's wide experience and knowledge in applying the best corrective measure.

The first step in applying Preventive Maintenance is making sure that the valves and fittings are right for working conditions.

Here was a renewable disc valve in the steam line to a turbine-type blower. It couldn't stand the "gaff" of constant throttling. The disc wouldn't last. No wonder the draft blower ran wild!

Preventive Maintenance counseled replacement with a Crane No. 14½P —a plug type disc valve designed for tough throttling jobs. Its materials and construction would safely resist the ravaging effects of throttled steam. It would give unvarying control of flow —keep the blower running evenly.

RESULTS: No more blackouts even after two years. The menace of interrupted boiler operation, fuel waste, even complete shutdown was eliminated with Preventive Maintenance. Another user of piping knows that the Crane Man can help get most for piping maintenance dollars. Because, Crane is not only the source of valves and fittings for every need, but of accurate information on their proper usage as well.

This case is based on the personal experience of R. B. H., a Crane Representative in our Minneapolis Branch.

TOUGH FLOW TAMED WITH CRANE BRASS PLUG DISC VALVES

In your boiler room—in any lines requiring severe throttling, you'll find these valves exactly right for the job. They're sound protection against trouble in blower, blow-off, and boiler-feed services, in drip and drain lines.

The unusual stamina of these Crane valves is in their plug-type disc and seat construction. Materials are just the right combination for highest resistance to the corrosion and erosion of actual working conditions. The wide seating area repels the damaging effects of wire-drawing and foreign matter; assures long-lasting tightness. The tapered disc provides easy, positive regulation of flow.

With Crane Plug Disc valves, you can apply money-and-trouble-saving Preventive Maintenance to all the *tough* spots in your piping. They're available in a complete range of pressure ratings. For 150 pound services, specify the No. 14½ P—in sizes up to 3 inches.

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Fuel Engineers Plan Test Code

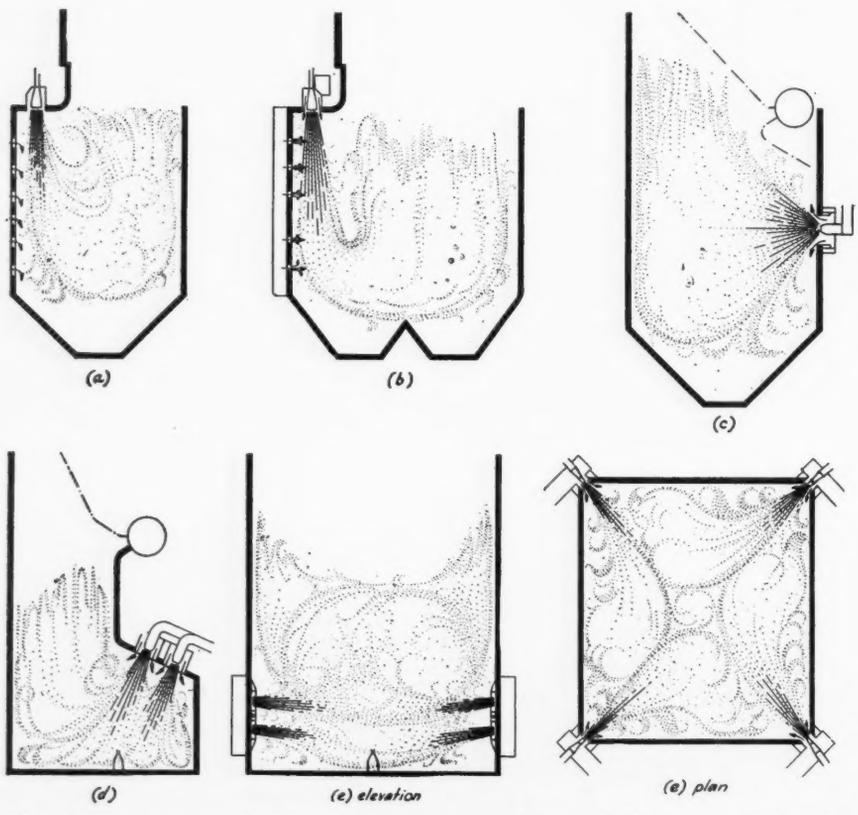
Joint meeting of ASME and AIME hears report of committee on a code for evaluating coal in combustion tests, and papers on turbulence in pulverized-coal furnaces, sampling characteristics of coal and steam generation in steel mills

► FUEL ENGINEERS from all parts of the country met at Birmingham, Nov 7-9, at the 4th annual joint meeting of the Fuel Division, ASME and the Coal Division, AIME.

Prominent on the order of business was the first report of a committee formed during the past year to consider and prepare a code for the evaluation of coal in combustion tests. Realizing that present test codes relate primarily to performance of equipment and include only incidental information concerning the fuel, this group aims at developing standard procedures for determining the combustion characteristics of various coals which enables them to burn at maximum efficiency or with the greatest ease of operation or with lowest maintenance costs.

At an organization meeting held in Philadelphia, Dec, 1939, the chairman, R L Rowan, appointed a sub-committee on aims and objectives, headed by A W Thorson. This sub-group reported at the second meeting of the main committee, held in Pittsburgh, Aug, 1940. At this time three additional sub-committees were formed to formulate portions of codes dealing with (1) information required to describe the coal as supplied to the combustion equipment, (2) observations to be made in tests to evaluate coal for use in underfeed stokers, and (3) observations to be made in tests to evaluate coal when burned in suspension. The heads of the respective sub-committees are: R F Stilwell, M A Mayers, and R M Hardgrove.

Discussing "Turbulence and Combustion in the Pulverized Coal Furance", B J Cross, Combustion Engineering Co, pointed out that turbulence is created first in the stream of coal and air, and later by interaction between the streams. A third effect is introduced by the confining influence of furnace walls. After analyzing the factors determining turbulence in the jet itself, Mr Cross described turbulence characteristics of various furnace arrangements (see diagram below) and showed how the effectiveness of turbulence may be measured by unburned carbon in the ash leaving the furnace. He presented some graphs of furnace draft showing pulsations believed to be associated with furnace turbulence.



Five burner types and furnace arrangements: (a) vertical, natural draft, (b) vertical, forced draft, (c) horizontal "turbulent" burner, (d) "impact" burner, (e) corner-fired burners

Percy Nicholls and B A Landry, Bureau of Mines, reported on a study of sampling characteristics of coals, in which the aim was to explain the factors and principles involved in evaluating the dependability of a sample. The study showed that a "lot of coal" has definite physical properties, namely, the physical properties of the pieces and those of the structure, expressed by the arrangement of the pieces relative to each other. These are "primary sampling characteristics."

The physical properties of the individual pieces which are of concern for sampling ash can be completely expressed by two "distributing curves" consisting of the ash percentage and the weight of the individual pieces, respectively, plotted against percentage cumulative weight of the lot of coal. It was shown that the number of increments required for a given sampling accuracy is related to a certain "compound sampling characteristic" of the lot of coal, which is a function of the primary sampling characteristics. Thus the number of increments required can be defined in terms of the properties of the lot of coal. Knowing the factors and quantities involved, it is possible to plan intelligently the sampling investigations and to coordinate the results.

H J Kerr, Babcock & Wilcox Co, compared operating results and design characteristics of steel-mill power plants, giving an analysis of factors delaying use of high steam pressures and problems to be solved in connection with higher steam temperatures. He described and illustrated numerous blast-furnace-gas boiler installations, typical of best modern practice.

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THE Nalco SYSTEM OF FEEDWATER TREATMENT

What is Adequate Protection for Electric Circuits?

▶ ADEQUATE PROTECTION of electric circuits and equipment against dangerous overloads must have as its basis a thorough understanding of circuit and equipment characteristics. Emphasis was placed on this fact by J L Wagoner of the Westinghouse Electric & Mfg Co in a recent address given at a meeting in New York City. Even though his remarks applied to circuits using No. 14 wire rated at 15 amp, supplying small devices, they are pertinent to an understanding of all circuit protection.

Curve *A*, Fig. 1, shows the current that a No. 14 wire will carry for a given time without exceeding the standard 54 F increase in temperature. For example, this wire will carry approximately 750 amp for 0.1 sec without overheating and 45 amp for one minute and keep within a safe temperature. Therefore, to protect adequately this wire under abnormal conditions, the protective device must open the circuit before the limits shown by curve *A* are exceeded. Many of the devices on these circuits are connected with No. 18 wire which should also be protected. Curve *B* shows the time that this size wire will carry a given current before the temperature rise equals 54 F. Even though this wire will carry about 300 amp for 0.1 sec without overheating, the 15 amp rated load of a No. 14 wire will cause it to exceed the temperature limit rise in 7 min.

Current Requirements

The current taken by different types of loads is shown by curve *C*, Fig. 2, which shows what happens when a 15-amp load of tungsten lamps is switched on. When the filament of these lamps is cold it has only about 0.1 the resistance it has at operating temperature. In 0.1 sec after the switch is closed the current inrush to the lamps is still in excess of 100 amp, but in about 2 sec it has decreased to normal value of 15 amp. An extensive field investigation was made of the starting current taken by motor-driven devices such as supplied from No. 14 wire circuits. These were found to fall within the shaded area, Fig. 2, which is well within the safe temperature rating of a No. 14 wire. The ideal protective unit for all these devices must not open the circuit on normal inrush currents of the motors or the lamps.

Mr Wagoner defined a short-circuit as any overload above the sum of the normal starting currents of the various loads on the circuit, because there is no obvious reason for time delay in the protective device, for a current above that value. Therefore, he said that instantaneous operation of a protective device on a 15-amp circuit breaker should start at about 200 amp, Fig. 3.

Mr Wagoner summarized the requirements of a successful protective device for a No. 14 wire, 15-amp typical circuit as one that would give 100% protection to the No. 14 wire, protect No. 18 wire under most conditions, allow harmless momentary overloads, and give instantaneous circuit opening for current values of 200 amp and above. Such an ideal protective device would have a time-current curve like *D* Fig. 3. A circuit breaker having or nearest approaching these characteristics would give the safest circuit protection. Such a breaker, said Mr Wagoner, with its requirements of time delay and instantaneous operation, would necessarily have to combine a thermal and a magnetic trip unit, which is now available.

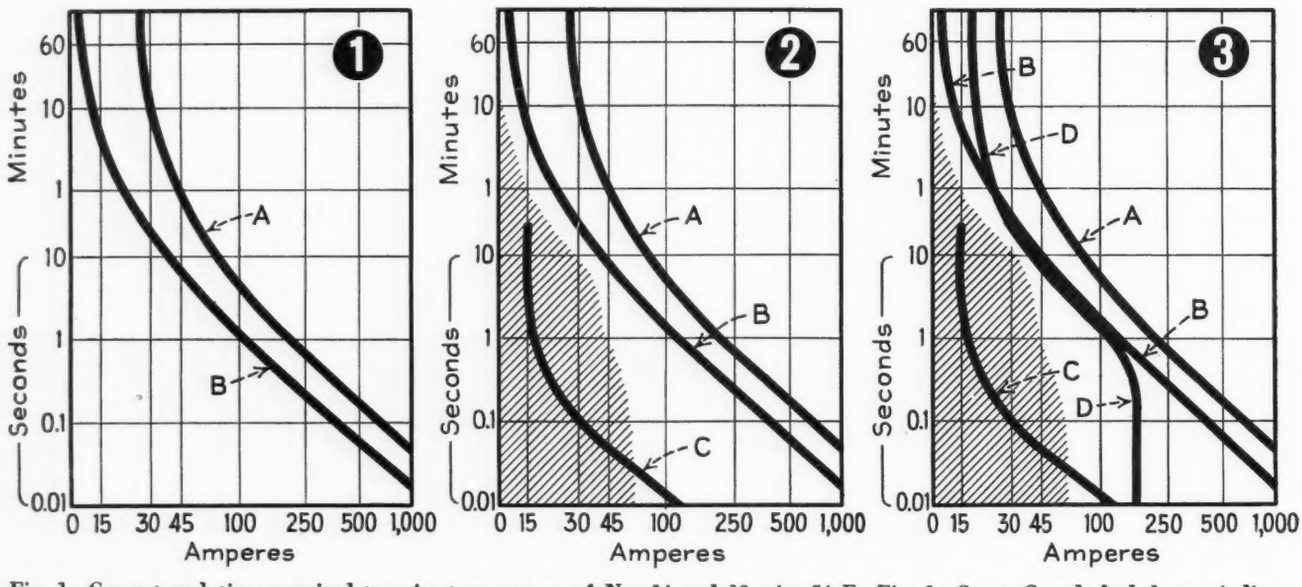

Fig. 1—Current and time required to raise temperature of No. 14 and 18 wire 54 F. Fig. 2—Curve *C* and shaded area indicate inrush currents of lamps and motors on No. 14 wire. Fig. 3—Same as Fig. 2, but with protective-device curve

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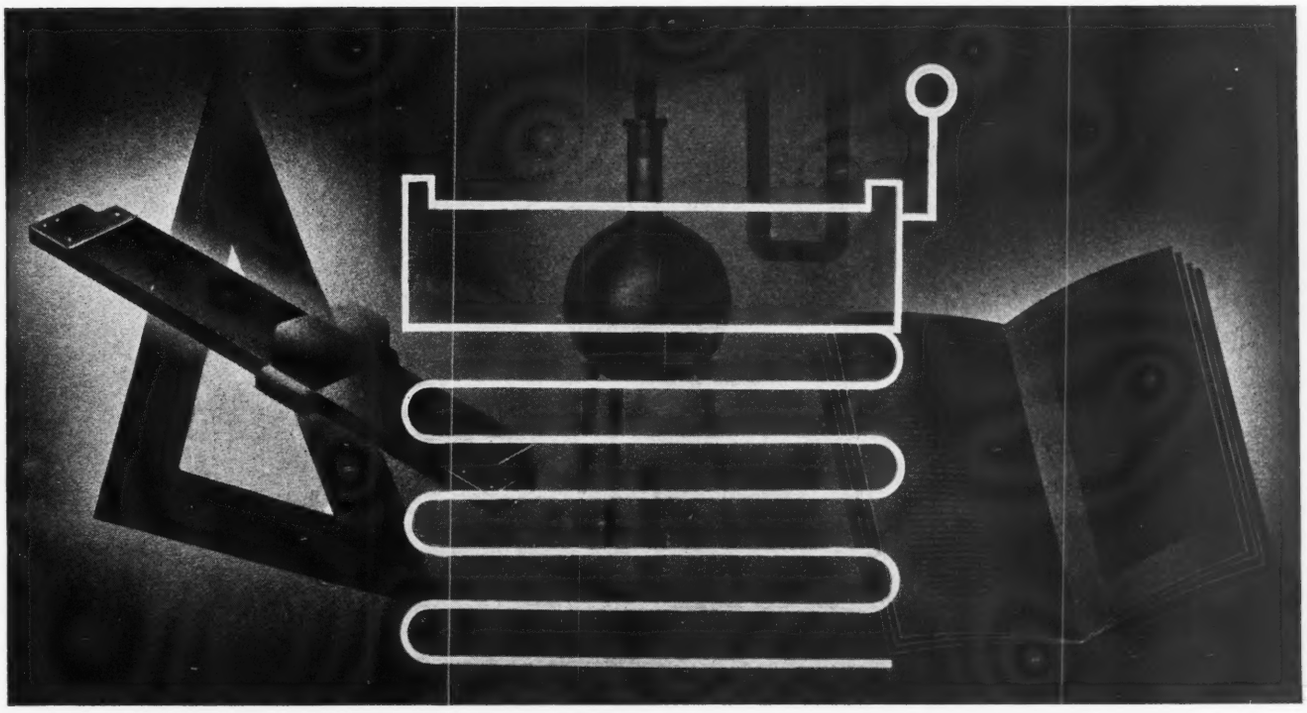

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SERVICE IN MEN—Scovill engineering representatives aid you in two ways. They first study your operating conditions and are then in a position to recommend the installation best suited to your needs. Secondly, they regularly go into the field to check on how tubes are performing in service, and to assist with your current problems.

SERVICE IN MANUALS—Scovill's many experiences in condenser and heat exchanger applications are the basis for the data contained in Scovill publications. A copy of the recently revised "Condenser Tubes" booklet is yours for the asking.

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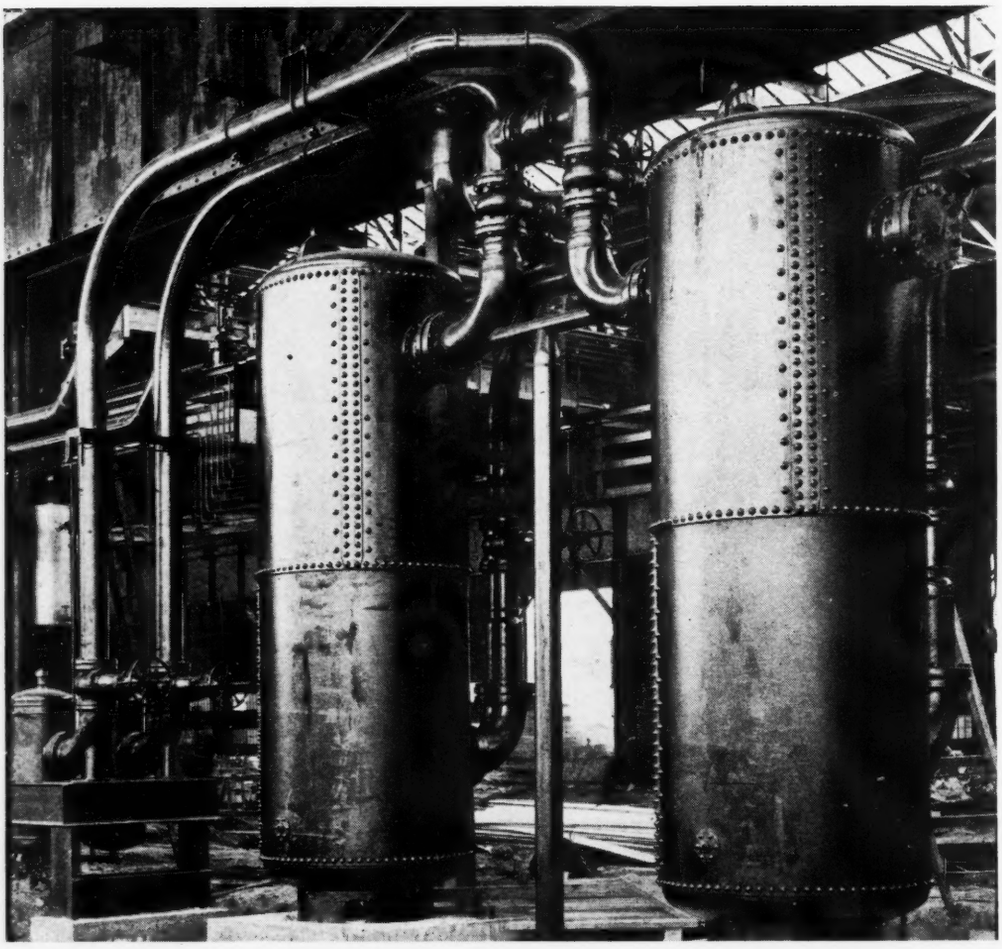

Fig. 1—Compressed air in receivers is double dynamite in a fire. Heat raises the pressure, softens the shell and sometimes seizes the valve. Moral: relieve the pressure before the tank gets hot

Watch These Fire Hazards!

Charles Wiggins tells what to do about air receivers, water tanks, boilers, welding tanks, chlorine gas, explosives, fuel-oil systems and fire pumps

▶ SOME INDUSTRIAL PLANTS have emergency duties posted and hold periodic drills so that each man will know what to do in case of fire. Others do not have such programs.

During normal operation one may never think of the various hazards that might arise if a fire were to break out in a plant. In the excitement of the actual fire, plans for action may take longer to put into effect than the emergency will permit.

This article will not attempt to go into the ramifications of industrial fire prevention or fire fighting, but will try to point out hazards of some equipment that might be under jurisdiction of the power engineer.

Air Receivers—Heat of a fire may very dangerously raise the pressure of compressed air in a receiver. For example, an increase in temperature from 70 to 500 F would boost 100-lb pressure to 193 lb. Normally, operation of the safety valve would prevent the pressure from exceeding safe limits. However, the valve may be located on piping some distance from the tank, or heat of the fire may cause valve seizure.

Excessive pressure building up in the tank may then cause a disastrous explosion. In case of fire, and if the compressed air is not needed for operating any fire-fighting or signalling apparatus, shut down the compressor and open the drain valve on the tank.

Hot- or Cold-Water Tanks—Here too, expansion may cause a serious explosion. POWER readers in the eastern part of this country may remember that just a year ago such an accident resulted in the death of two people. If the tank is a cold-water vessel used in any way with sprinkler systems or other fire-fighting service, operation of the tank should be governed strictly by fire-department and/or fire-insurance-company regulations.

If it is a hot-water tank, or a cold-water tank having nothing to do with fire-fighting service, it had best be left full of water unless the weight is considerable and the tank is located where collapse of its support might cause

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Watch These Fire Hazards

(Continued from page 118)

further hazard to life and property. In such case the tank drain should be opened to relieve the weight. If there is no danger of collapse of the tank support, leaving the tank full of water may prevent possible damage through overheating. Where the tank is left full of water, a vent valve or faucet should be opened to prevent pressure building up.

Boilers—Should fire threaten the boiler room where the boilers are used to operate steam-driven fire pumps, there is little that can be done except to maintain operation until the last possible moment. Usually if the boiler house is doomed, the steam pumps, too, will be out of commission.

Before leaving a steam boiler under pressure exposed to a fire, it is advisable to take drastic steps to reduce the hazard of explosion and to protect the boiler against damage in so far as possible. The fire under the boiler should be extinguished. In the case of a stoker- or hand-fired boiler, there may not be time to pull the fire. A fire hose may be used on it if convenient, or the fire may be banked with ashes or green coal. The lifting levers on the safety valves should be blocked open with noninflammable blocks and the water level should be left as high as possible before abandoning the boiler plant.

Welding Tanks, Oxygen and Acetylene Bottles—If these units are exposed to high temperatures a serious explosion may result. The bottles should be removed from possible contact with fire.

Chlorine-Gas Bottles are often used in the power or industrial plant for algae control at water-intake systems. The explosion of such a unit would be doubly dangerous since both the explosion itself and the toxic gas released could cause fatalities. Like the welding units, these bottles are portable, and should be removed from possible exposure to fire.

Explosives—Chemical and other industries sometimes have installed pressure vessels containing liquids or materials that are explosive if exposed to fire. Fire-department and insurance regulations should be adhered to rigidly with such units. If a fire does break out and these units appear likely to be exposed, the fact should be made known immediately to the person in charge of fighting the fire. All not so engaged should be cleared from the vicinity at once.

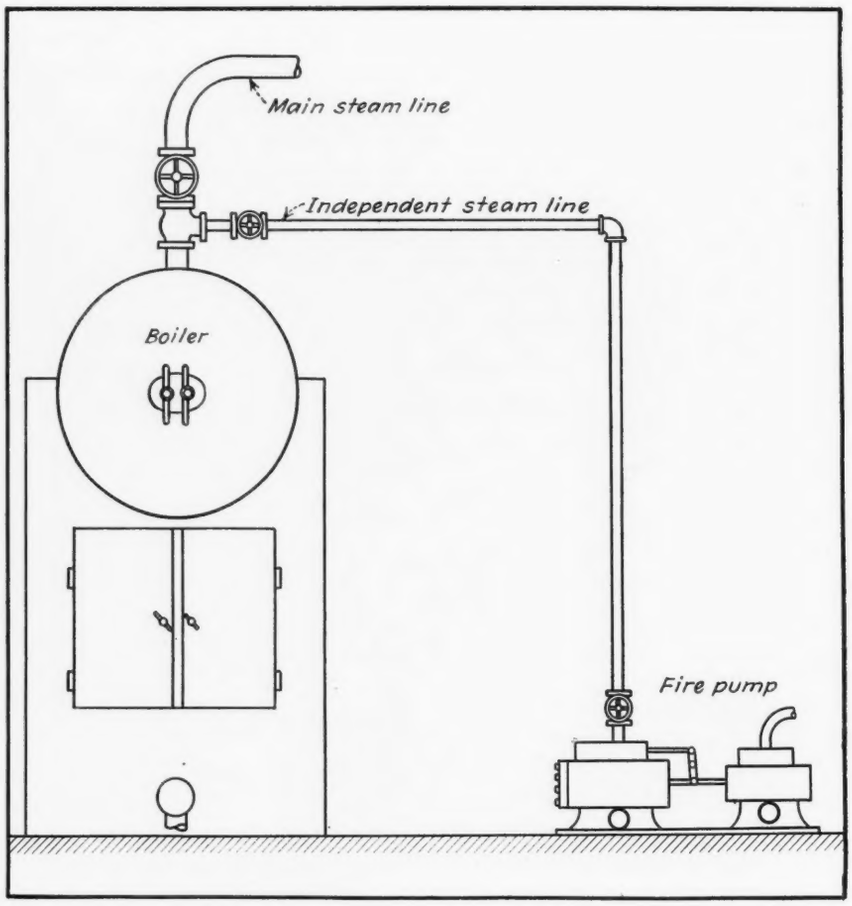


Fig. 2—Fire-pump steam line should be tapped off between boiler and main boiler stop valve, so pumps can operate even if main steam lines fail or must be shut off

Fuel-Oil Systems—Most oil-storage tanks are safely underground as required by many fire-insurance regulations. In case of a fire in the boiler room the shut-off valve nearest the tank in the fuel-oil-supply line should be closed immediately. This valve is often of the lever type and weighted, but held open by a fusible link. In case this link is exposed to high temperatures, it melts, and the weight closes the valve.

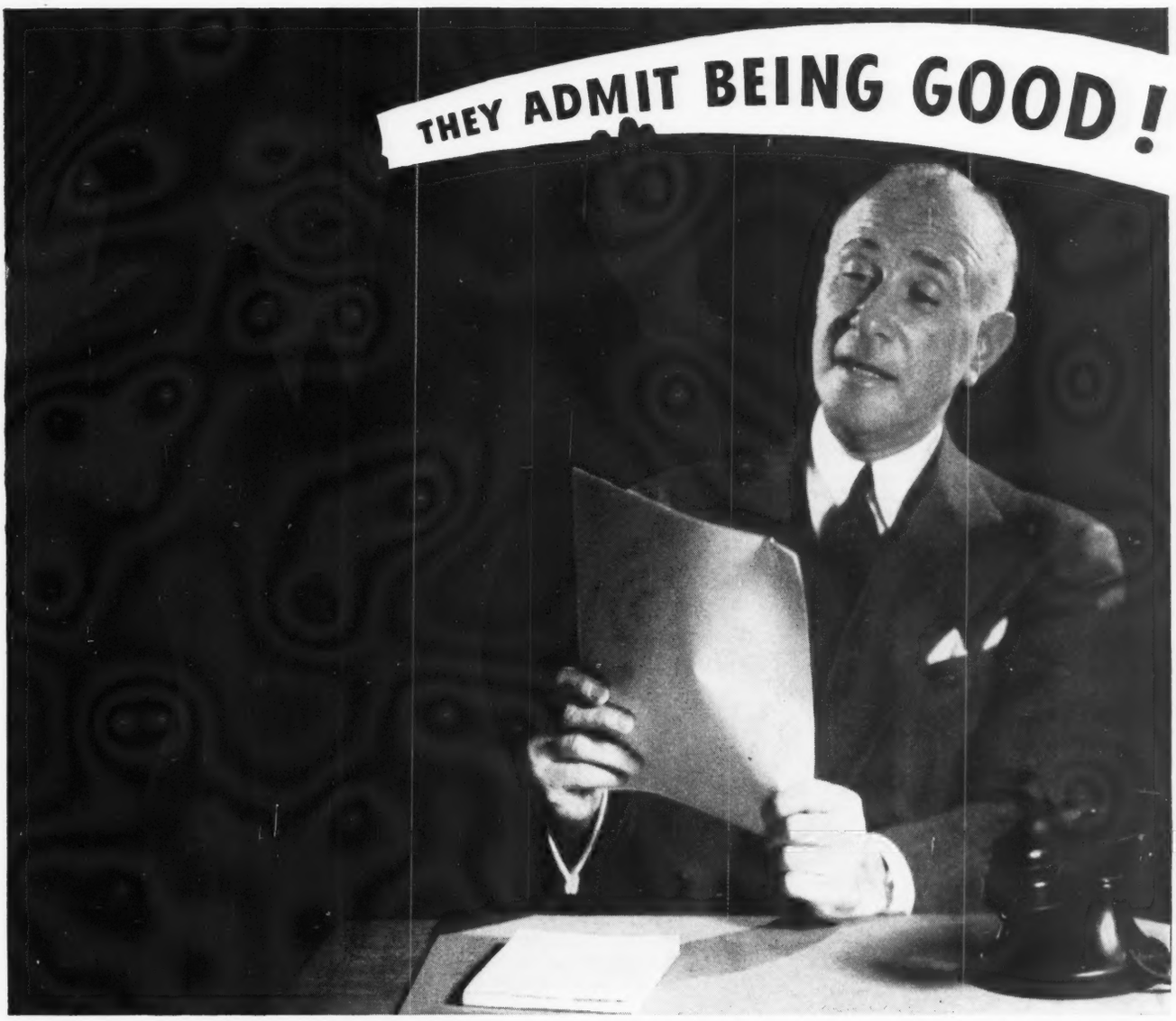
Installation of a boiler that is to supply steam for a fire pump, as well as for power, heat, or process, should deviate from customary procedure in that the steam line to the pump should be an independent line. This line should connect directly to the boiler as shown in the sketch, and it should not be on the outside of the main stop valve. By this procedure, steam will be available for the fire pump even though the main stop valves are closed, making it unnecessary to charge the entire steam line. The latter might be impossible in case of damage to the main-line piping.

Compliance with these few suggestions, and unfailing adherence to all fire-department and fire-insurance regulations, may permit the engineer to play an intelligent part in such emergencies.

Welding Booklets Available

PRACTICAL LESSONS IN ARC WELDING. *Published by Hobart Brothers Co, Troy, Ohio. 218 pages, paper bound, price $.50.*—Consists of Part II of Hobart book, "Arc Welding and How To Use It" and covers practical lessons in arc welding, including such chapters as welding with bare electrodes, welding and cutting with coated electrodes, striking and manipulating the arc, and preliminary instructions.

COURSES IN OXYACETYLENE WELDING AND CUTTING. *Published by Air Reduction Sales Co., 60 East 42nd St., New York. Price: classroom exercises $.50, lecture book $1.00.*—Classroom exercise book impresses fundamentals on those interested in getting a working knowledge of welding, and the lecture book, which works in conjunction with the exercise book, describes the history of welding, properties of materials, theories and practical applications in industry.



ALTER EGO: Literally "one's other self"—the still, small voice that questions, inspires and corrects our conscious action.

ALTER EGO: How many have offered you a "good-as-Fleetweld" rod . . . and are they confessing or bragging?

Well, here's the third different welding rod proposition that lays eloquent emphasis on the claim that it's as good as "Fleetweld." *That's stimulating.*

ALTER EGO: No, it's emulating. Emulation admires and strives to imitate great actions. It's a human trait.

That prompts me to ask myself—"Why is 'Fleetweld' taken as the standard of welding electrode comparison?"

ALTER EGO: Maybe Lincoln can give us the FACTS and we can judge for ourselves.

• •

LINCOLN SUGGESTS: To find out why "Fleetweld" is the standard of comparison for welding quality and economy, TRY IT! Compare it to other electrodes. In what ways? See the 30-Point Check Chart on Page 5 of the New "Weldirectory." This 56-page procedure guide (gratis) gives all the FACTS about 37 Lincoln Electrodes for welding and hard-surfacing—where to use them—how to use them—what weld properties to expect.

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POWER LINES

Westinghouse Expands

The Westinghouse Steam Div Works, near Philadelphia, Pa., will expand present facilities at a cost of more than $9,500,000, to assure on-time delivery of turbines for 45 fighting ships of the United States Navy. R A McCarty, manager, explained, "The plant expansion program includes a 3-story headquarters building, now under construction, and which will be occupied in December. Additional manufacturing space will be provided and present facilities rearranged to permit top-speed manufacture. Present rates of production will be increased by four times for some naval equipment. Over $5,000,000 worth of machine tools and other manufacturing equipment are being installed as rapidly as they can be obtained.

"Manufacture of big power apparatus is always a matter of months, even years. By our new moves we are determined to keep deliveries on schedule. In 1940 we will turn out nearly $10,500,000 worth of the machinery now on order. In 1941, delivery of another $22,000,000 worth will be made, and in 1942 another $25,500,000. We have scheduled about $6,500,000 of our backlog for 1943 and later.

"Orders for 57 land steam turbines are being filled. These are prime movers for power plants throughout the nation. Some 70 mechanical drive turbines, mainly to provide power for industrial machinery, are also being constructed for land use."

Sikeston Adds Diesel

Sikeston, Mo., will purchase a 1,400-hp diesel, to cost $67,000 and to be added to the four other units at the municipal light and power plant. The new engine will increase total capacity of the plant to 5,250 hp.

ASRE Meets Dec 3-5

With a membership increase during the past year and a half of 40%, the American Society of Refrigerating Engineers will hold its annual meeting December 3, 4 and 5 in the Hotel Commodore, New York. Two informal conferences, one on air conditioning operation and one on locker plants, are scheduled for the first afternoon, Tuesday Dec. 3. At the air conditioning session, widely known engineers who furnish air conditioning for large groups will explain most common criticisms and serious operating problems.

Some of the papers which will be of interest to power men are: "Personnel Problems in the Defense Program," by T A Armstrong, Westinghouse Electric & Mfg Co; "Aluminum in Refrigerating Equipment," Robert B Mears, Aluminum Co of America; "Vibration Isolation," J G Aldinger and E T P Neubauer, York Ice Machinery Corp; "Heat Interchangers," David Crampton, Wallace & Tiernan Co; and "Status of Safety Laws in Various Parts of the U. S.," C F Brooks, National Electrical Manufacturers' Assn.

1940 Welding Awards Presented at AWS Meeting

The 1940 Miller Memorial Award and the Lincoln Gold Medal for 1939-40 were features of the opening session of the American Welding Society's annual meeting on October 21. The Samuel Wylie Miller Memorial Medal was awarded to William Spraragen, technical secretary of the American Welding Society and editor of "The Welding Journal." Award of the Lincoln Gold Medal, donated to the American Welding Society by James F Lincoln, president of the Lincoln Electric Co, was made to Messrs J H French and T N Armstrong, Jr, of the International Nickel Co, Inc, New York City.

The award of the Miller Medal was made for conspicuous contributions to the art and science of welding during 21 years in the field, also for the quality and intensity of the service which has been marked throughout by unusual energy, loyalty and integrity. The Lincoln Award, presented each year to the author of the paper which contributes most to the year's development of welding, was made for "Weld Hardening of Carbon and Alloy Steel", published in the October, 1939, issue of the Welding Journal, and presented at the annual meeting in Chicago, Oct. 23-27, 1939. The paper occupies 9 pages in the "Journal", contains 19 charts and covers test methods, carbon steels, ternary alloy steels, welding speed and plate thicknesses, pre-cooling, maximum hardness available, preheating steel with high hardening capacity, comparison of complex alloy and carbon steels.

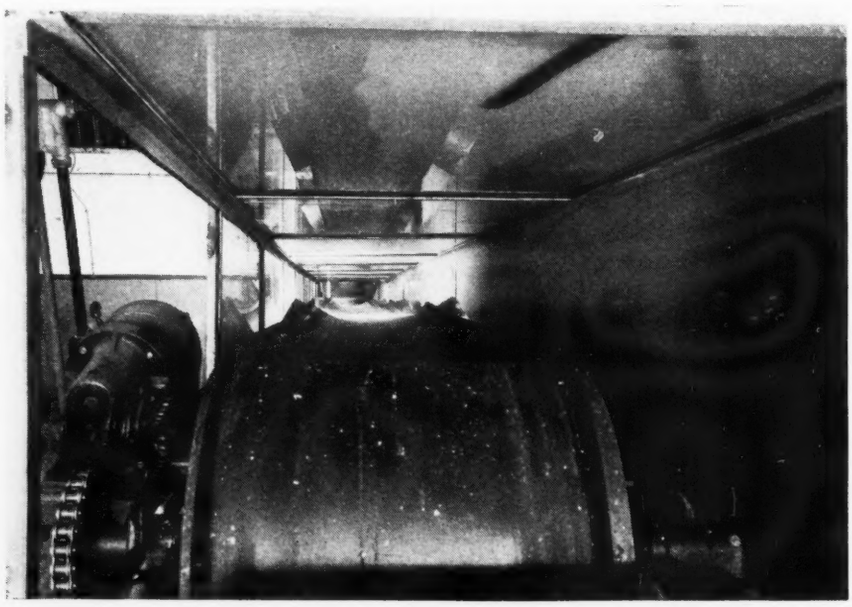
Endicott St Station Plans Another Addition

Plans are under way for expansion of the Endicott St station of the Peabody, Mass., municipal light department. A new boiler and turbine-generator unit, to cost about $325,000, will be added. Existing plant has two boilers and a 1500-kw generating unit about 20 years old, additional energy requirements being purchased from power plant of A C Lawrence Leather Co. It is planned to install equipment which will enable the town to sell live steam to various industrial plants in the vicinity of the station.

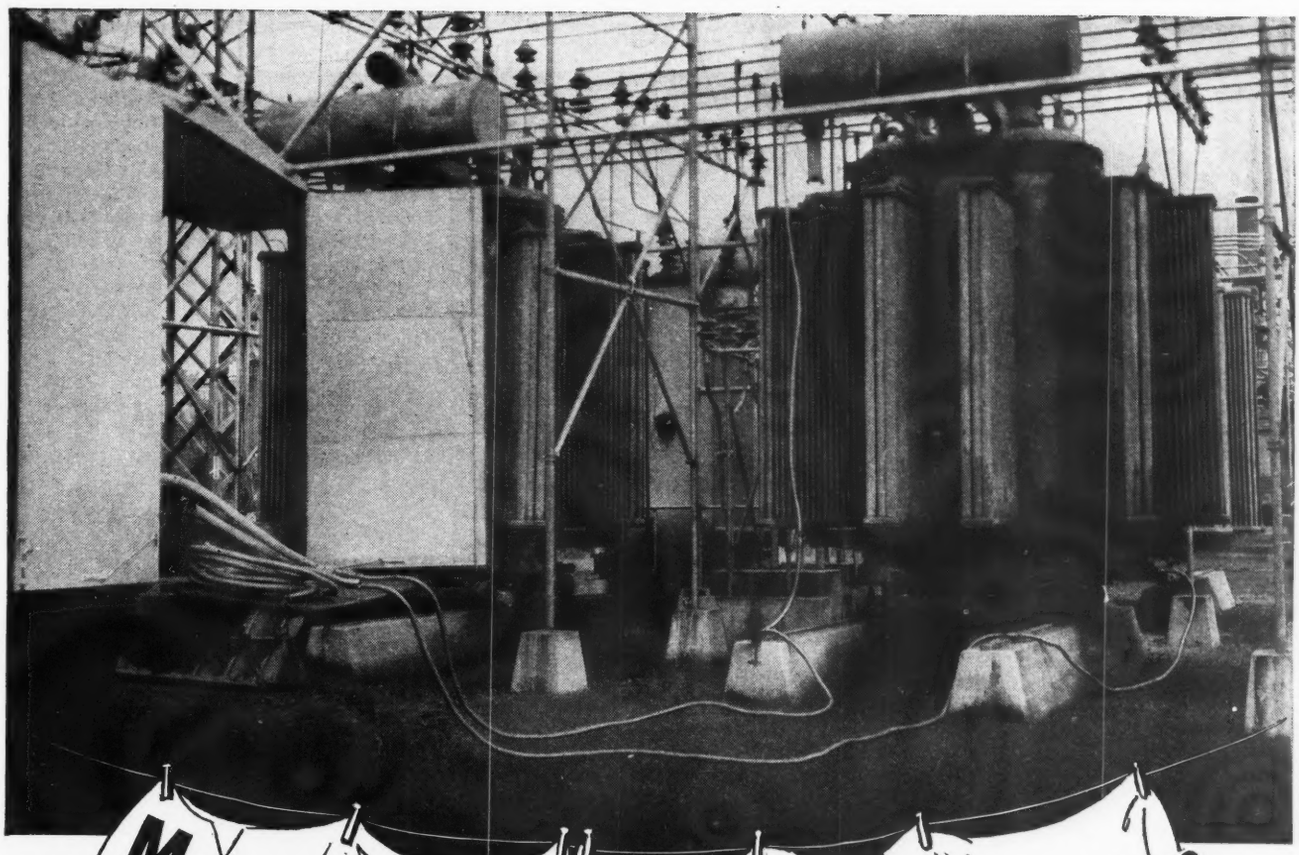
Chas R Huntley Station to Add 80,000 kw

The Charles R Huntley Steam Station of the Buffalo Niagara Electric Corp will add 80,000 kw of generating capacity to its present 465,000 kw. The project will cost an estimated $6,000,000. The order for the building of the 60-cycle, 80,000-kw,

IN A GLASS BY ITSELF



It's no museum piece and there's nothing fragile about this conveyor belt—this installation is operated by an eastern rayon manufacturer to convey broken pulp. The glass case was devised to prevent moisture loss during an important process step



Monday morning at the sub-station

Here transformer oil gets a profitable washing; it is conveyed safely, surely from transformer to portable filter and back again through clean, dependable American Flexible Metal Hose.

SLUDGY transformer oil has to be washed just as shirts and sheets to restore its efficiency and prolong its useful life. To do this, a truck with portable filter backs up to the transformer and pays out two lengths of flexible metal hose, one to the drain cock, the other to the overhead oil reservoir. In the process, the hose is yanked across rough, sharp ground, coiled and uncoiled frequently and subjected to a certain amount of pressure as the filtered oil is pumped back into the reservoir. It is significant that for such abusive treatment, American Metal Hose is invariably the choice.

There are hundreds of other uses for the products of American Metal Hose that are daily saving money and speeding production for power plants all over the country. There's American Seamless, as pressure-tight as the seamless tube from which it is made, yet as flexible as garden hose; use it for conveying steam, gas, oil and other liquids. And there's American capillary tubing, providing all the protection of metal for delicate instruments without sacrificing flexibility.

Read about these products in our two new books illustrated here. A note to us will bring them to you by return mail. 40272

ANACONDA

American Metal Hose

The American Metal Hose Branch of The American Brass Company, General Offices: Waterbury, Connecticut

In Canada: Anaconda American Brass Ltd., New Toronto, Ontario • Subsidiary of Anaconda Copper Mining Company

steam-driven turbine generator has been given to the General Electric Co.

A feature of the turbine is that it will be one of the first large condensing units built in a single casing and using steam at 1250 lb per sq in. Steam will be delivered to the turbine at 900 F. The generator will be hydrogen cooled, and the ash residue from the coal burned in the furnace will be tapped off in molten state and quenched with water to a consistency of coarsely granulated sugar. This method of ash removal was pioneered in the Huntley Steam Station.

Professional Engineers Meet

The New York State Society of Professional Engineers, in their fall convention at Jamestown, N. Y., considered a suggestion that "engr." be used as an abbreviation of the title engineer when prefixed to a name. The society's executive board approved the suggestion insofar as it would affect the state body. Other resolutions were presented and reports were presented by Herman F Lane, Albany, Charles W Burke, Brooklyn, George A Dorfman, and Dr David B Steinman, New York.

GAS TURBINE MEDAL

Dr Adolph Meyer, managing director of Brown, Boveri & Co, Baden, Switzerland, and pioneer in the gas-turbine field, was recently honored by the Institution of Mechanical Engineers in London, with the George Stephenson Medal reproduced above in recognition of his work in developing the gas turbine

Here's a Slang Dictionary for All Welders

Rather picturesque speech, usually attributed to jitterbugs, hep cats, and the like, sometimes comes from industrial workers, who have speech equally or more so interesting and amusing than those mentioned. The Welder's Dictionary, compiled by Charles H Jennings, Westinghouse Electric welding expert, gives some of the common slang used in welding shops throughout the country.

A *banana weave* is a weaving motion applied to the electrode which has the characteristic shape of a banana. *Dingle balls* are molten particles of spatter falling from the electrode when welding in vertical and overhead positions, while a *fish eye* is a characteristic marking sometimes found on the fractured surface of a tensile specimen consisting of a central flaw surrounded by a bright circular area; surface of the flaw is slightly concave and disposed approximately at right angles to direction of applied stress.

Grapes are elongated particles of weld metal hanging from the surface of an overhead weld. A *jazz-box* (not to be confused with a "juke box"), is a small size ac welding transformer. An electric arc which makes sharp crackling sounds is known appropriately enough as a *snappy arc*, and *spalls* are small particles of metal not comprising part of the weld that have been thrown from the electrode or from the deposited metal while still molten.

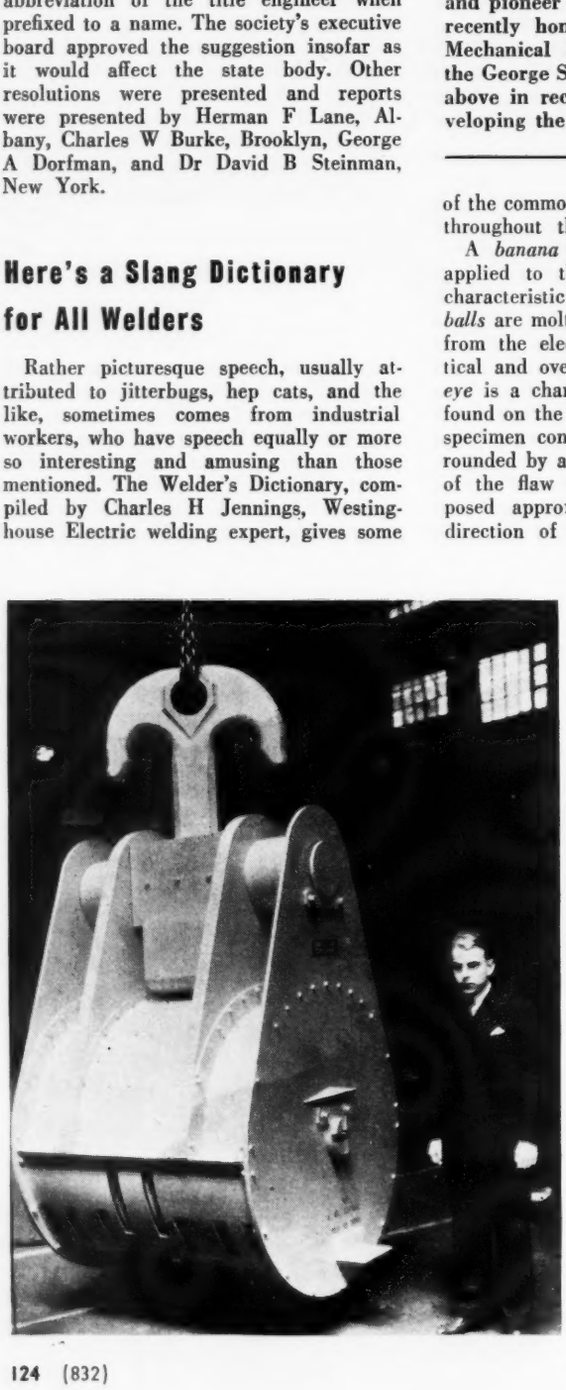
When you're told to "watch for the *volcano*" you will know that it is an eruption occurring after the first layer on a multiple-layer weld which is accompanied by an explosion and shower of molten metal, caused by the explosion of gas inclusions in the under layers.

Power Factor Discussed At Niagara Meeting

More than 300 plant engineers, electrical superintendents, maintenance and construction men, attended the first fall meeting of the Electric Association of the Niagara Frontier at the Hotel Statler in Buffalo. Principal speakers were M T Alimansky, power-factor engineer of General Electric Co, and Merrill E Skinner, vice-president of the Buffalo Niagara Electric Corp, who discussed low power factor and simplified rate schedule, respectively. Mr Skinner is president of the Electric Association of the Niagara Frontier.

Show and Exhibit Schedule Published

The Exhibitors Advisory Council has published a 34-page booklet containing important information on American Shows and Exhibits for 1941. This master schedule is classified to cover 50 different industries or activities and includes approximately 350 shows. Data on each exhibit or show to be held in 1941 include the name of the exhibit, date, location, sponsor and name and address of permanent secretary or show manager. While compiled primarily for members of the council, copies for non-members are available at $5.00 each from the Exhibitors Advisory Council, 120 Greenwich St, New York.



THERE'S A HOOK TO THIS PICTURE

Here's one of the hooks for two 350-ton cranes built by the Whiting Corp for the Grand Coulee hydroelectric plant. Each crane consists of a 73-ft traveling bridge, which mounts two 175-ton trolleys, making a total lifting capacity of 350 tons. Special lifting beams permit using the two cranes jointly to lift loads up to 625 tons. Each trolley requires 1700 ft of 1⅜-in. steel wire rope operating over a drum 60 in. in diameter. Complete, each crane weighs about 300 tons

Precision Instruments Need a Spider Farm

With a tensile strength 50% higher than that of steel, natural spider gossamer is still by far the best material for crosshairs in precision scientific instruments. Human hair is far too thick, silk is both too thick and becomes fuzzy with lint, no wire can be drawn fine enough to be suitable, yet spider gossamer can even be split if necessary to get an ultra-fine strand.

Practically all America's spider gossa-

(*Continued on page 136*)

"I'M TOUGH ON MOTORS!"

— Says E. H. Humberstone, Superintendent, Marble Cliff Quarries Co., Columbus, Ohio. And He Adds — "That's Why I Use Allis-Chalmers Lo-Maintenance Motors in Our Plants — 187 of Them!"

Another true case history from the Allis-Chalmers files that proves **"IT PAYS TO BUY THE EQUIPMENT THAT PAYS FOR ITSELF!"**

ONE OF 187 ALLIS-CHALMERS LO-Maintenance Motors in use in the Marble Cliff Quarries Co. plants, this 10-hp motor drives a double-deck screen . . . was installed in 1925. Service costs on this motor in fifteen years to date have been **zero!**

A STONE process plant is a good place to get the low-down on motor performance. Abrasive stone dust fills the air . . . loads are heavy . . . and costs are closely watched!

That's how conditions are at the Marble Cliff Quarries Company plant, Columbus, Ohio . . . conditions that can wreck an ordinary motor in a few months. And because Marble Cliff Quarries want uninterrupted service . . . long motor life . . . low power costs . . . they've equipped their plants with 187 Lo-Maintenance Motors . . . practically a 100% representation for Allis-Chalmers!

But read what E. H. Humberstone, superintendent, has to say —

"We make flux for the steel industry, and that means we must keep close watch on our costs. Often our motors run 24 hours a day, for months at a time. Yes, I'm tough on motors — have to be! But for years we've given first choice to Lo-Maintenance Motors because we have found they give longer service with less servicing."

Your Best Buy is Lo-Maintenance!

What Mr. Humberstone says is being backed up by hundreds of other production men . . . men who want the low-cost, money-saving service Lo-Maintenance Motors give them . . . in reduced power costs . . . in longer life.

For in Allis-Chalmers Lo-Maintenance Motors you get performance that's more than just a rated horsepower. It's performance based on full-measure construction — indestructible rotor . . . distortionless stator . . . high carbon steel frame . . . no skimp or stint anywhere. These, plus all the other Lo-Maintenance features, make it the best motor buy for you.

For full information on how these motors can help you cut your power costs, see the trained engineer in the district office near you, or write Allis-Chalmers, Milwaukee. A 1294

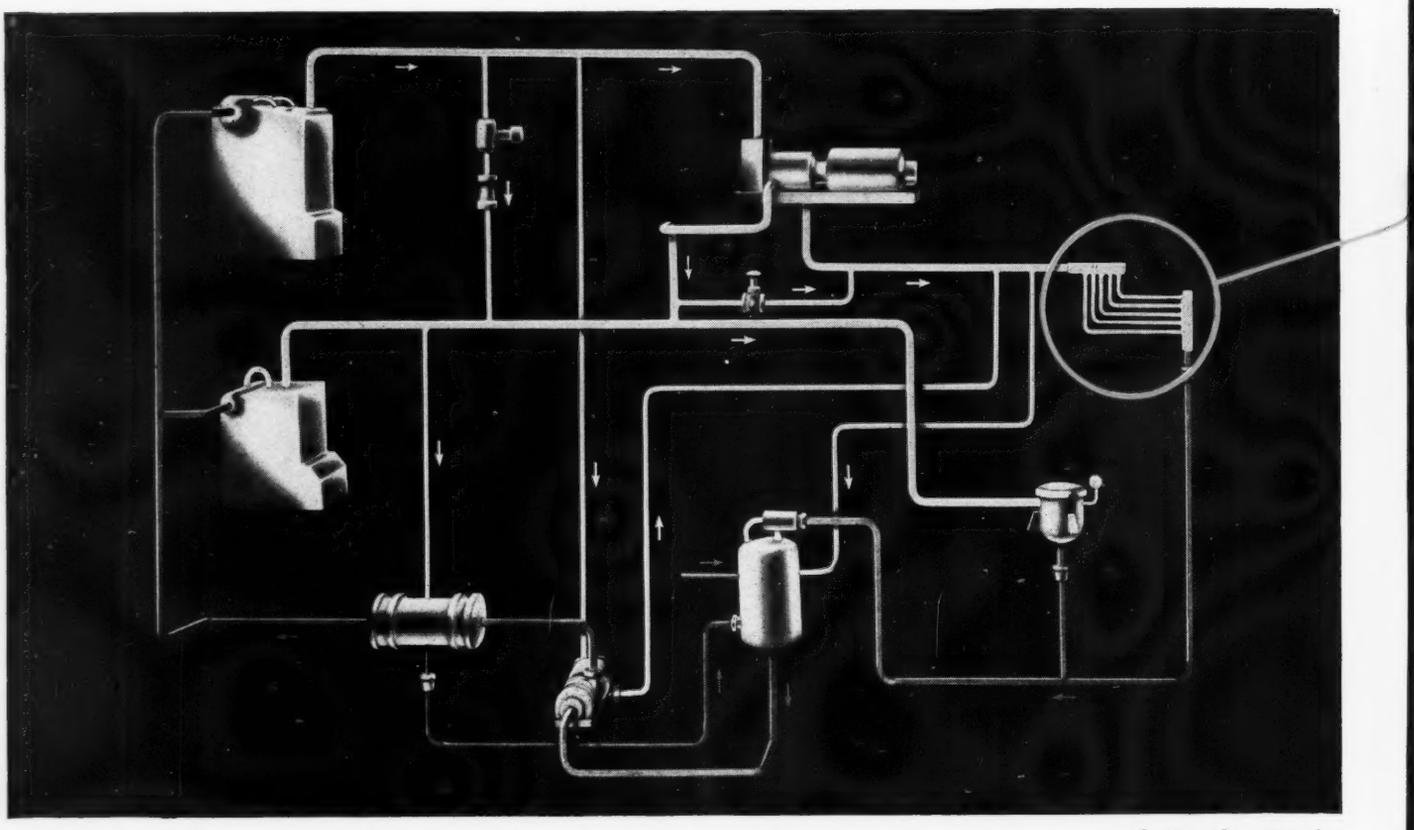
Over 90 Years of Engineering Superiority Work for You When You Specify Allis-Chalmers!

ALLIS-CHALMERS

MILWAUKEE · WISCONSIN

FROM *GOOD* POWER HOOKUPS

FOR 2-PIPE HEATING SYSTEMS . . .



Courtesy—Power Magazine

HOOKUP #25 **Large steam needs for cooking, laundry and heating, typical of institutions, determine this hospital hookup. Original plant supplied only steam; high-pressure boilers and an extraction backpressure turbine now meet power load while supplying steam for process and 2-pipe heating system at two pressure levels. Reducing valves tie pressure levels together; steam-driven auxiliaries exhaust to l-p header. Old boilers are operated during heating season to meet increased steam demand.**

WHEN heating systems are classified according to the method of returning condensate from the system, they are known either as gravity or vacuum systems.

In the heating system opposite, condensate is returned to a receiver which must be sufficiently below the lowest heating unit and return pipe to permit the return by *gravity.* Of interest in this diagram is the fact that the heating system is designed to take steam from three sources:—Turbine Exhaust, Feed Pump Exhaust and from a High Pressure Line through a Reducing Valve.

Perhaps we should note again, however, that the diagrams in this series are not piping recommendations—but merely serve to show the basic points of control in a typical system. Valves at each control point are indicated and identified with a key letter. This corresponds with the specific Figure Numbers in the table which Jenkins Engineering Advisory Service recommends for each service.

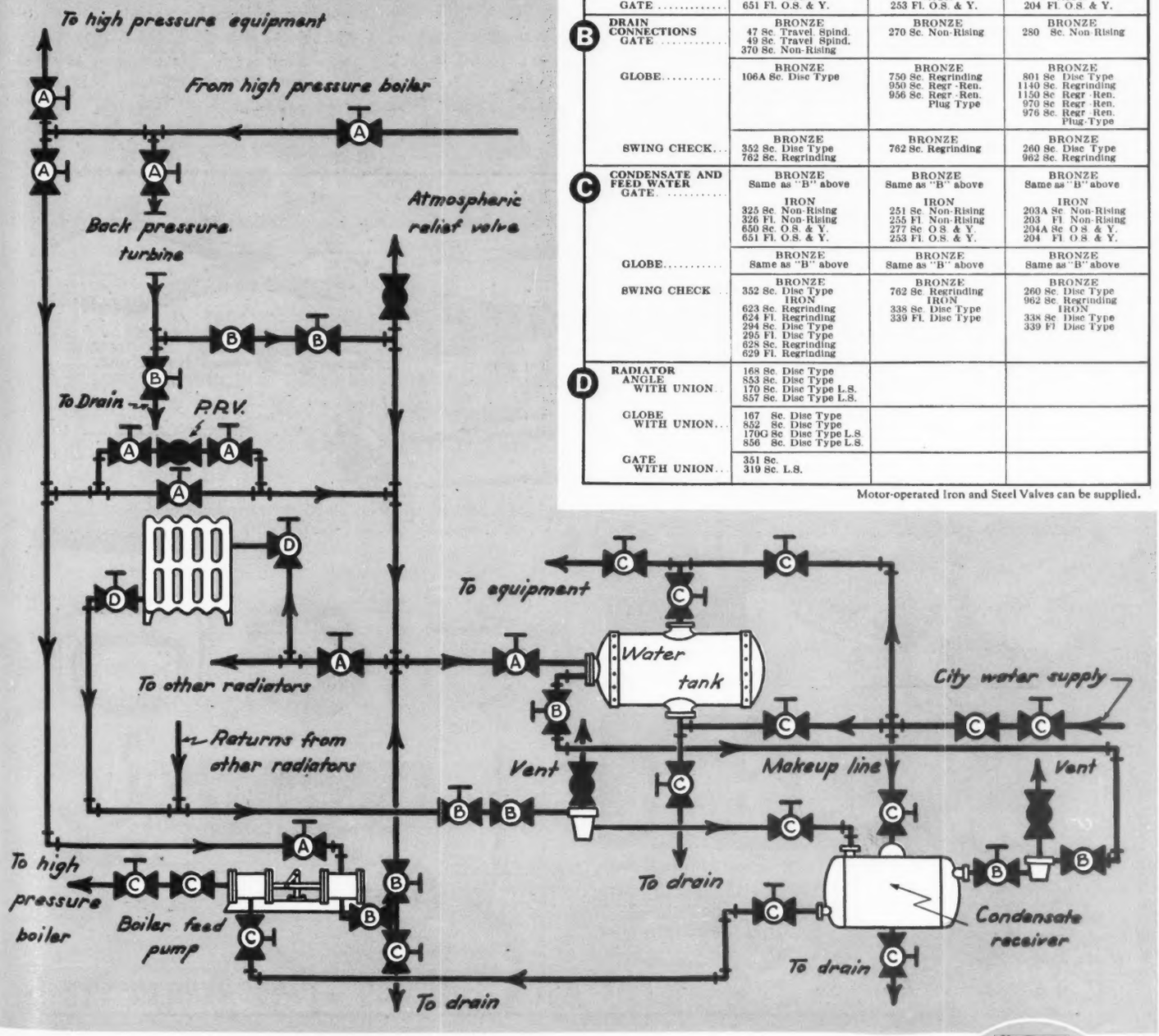
NEXT ISSUE—VACUUM HEATING SYSTEMS

IN VALVES *Jenkins* GIVES YOU EVERYTHIN

. . . TO *GOOD* VALVE PRACTICE

Jenkins RECOMMENDS . . .

CONNECTIONS FOR HEATING SYSTEM USING EXHAUST STEAM



REFERENCE CHART TO JENKINS FIGURE NUMBERS FOR 2-PIPE HEATING SYSTEMS

		Standard	Medium	Extra Heavy
A	HIGH AND LOW PRESSURE HEADERS GLOBE	IRON 612 Sc. Regrinding 613 Fl. Regrinding 141 Sc. Disc Type 142 Fl. Disc Type	IRON 744 Sc. Disc Type 775 Fl. Disc Type 918 Sc. Regrinding 919 Fl. Regrinding	IRON 162A Sc. Disc Type 162 Fl. Disc Type 922 Sc. Regrinding 923 Fl. Regrinding
	ANGLE	IRON 614 Sc. Regrinding 615 Fl. Regrinding 143 Sc. Disc Type 144 Fl. Disc Type	IRON 776 Sc. Disc Type 777 Fl. Disc Type 920 Sc. Regrinding 921 Fl. Regrinding	IRON 163A Sc. Disc Type 163 Fl. Disc Type 924 Sc. Regrinding 925 Fl. Regrinding
	GATE	IRON 651 Fl. O.S. & Y.	IRON 253 Fl. O.S. & Y.	IRON 204 Fl. O.S. & Y.
B	DRAIN CONNECTIONS GATE	BRONZE 47 Sc. Travel. Spind. 49 Sc. Travel. Spind. 370 Sc. Non-Rising	BRONZE 270 Sc. Non-Rising	BRONZE 280 Sc. Non-Rising
	GLOBE	BRONZE 106A Sc. Disc Type	BRONZE 750 Sc. Regrinding 950 Sc. Regr.-Ren. 956 Sc. Regr.-Ren. Plug Type	BRONZE 801 Sc. Disc Type 1140 Sc. Regrinding 1150 Sc. Regr.-Ren. 970 Sc. Regr.-Ren. 976 Sc. Regr.-Ren. Plug-Type
	SWING CHECK	BRONZE 352 Sc. Disc Type 762 Sc. Regrinding	BRONZE 762 Sc. Regrinding	BRONZE 260 Sc. Disc Type 962 Sc. Regrinding
C	CONDENSATE AND FEED WATER GATE	BRONZE Same as "B" above IRON 325 Sc. Non-Rising 326 Fl. Non-Rising 650 Sc. O.S. & Y. 651 Fl. O.S. & Y.	BRONZE Same as "B" above IRON 251 Sc. Non-Rising 255 Fl. Non-Rising 277 Sc. O.S. & Y. 253 Fl. O.S. & Y.	BRONZE Same as "B" above IRON 203A Sc. Non-Rising 203 Fl. Non-Rising 204A Sc. O.S. & Y. 204 Fl. O.S. & Y.
	GLOBE	BRONZE Same as "B" above	BRONZE Same as "B" above	BRONZE Same as "B" above
	SWING CHECK	BRONZE 352 Sc. Disc Type IRON 623 Sc. Regrinding 624 Fl. Regrinding 294 Sc. Disc Type 295 Fl. Disc Type 628 Sc. Regrinding 629 Fl. Regrinding	BRONZE 762 Sc. Regrinding IRON 338 Sc. Disc Type 339 Fl. Disc Type	BRONZE 260 Sc. Disc Type 962 Sc. Regrinding IRON 338 Sc. Disc Type 339 Fl. Disc Type
D	RADIATOR ANGLE WITH UNION	168 Sc. Disc Type 853 Sc. Disc Type 170 Sc. Disc Type L.S. 857 Sc. Disc Type L.S.		
	GLOBE WITH UNION	167 Sc. Disc Type 852 Sc. Disc Type 170G Sc. Disc Type L.S. 856 Sc. Disc Type L.S.		
	GATE WITH UNION	351 Sc. 319 Sc. L.S.		

Motor-operated Iron and Steel Valves can be supplied.

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#25 OF A SERIES designed to help in your selection of JENKINS VALVES

Number 101

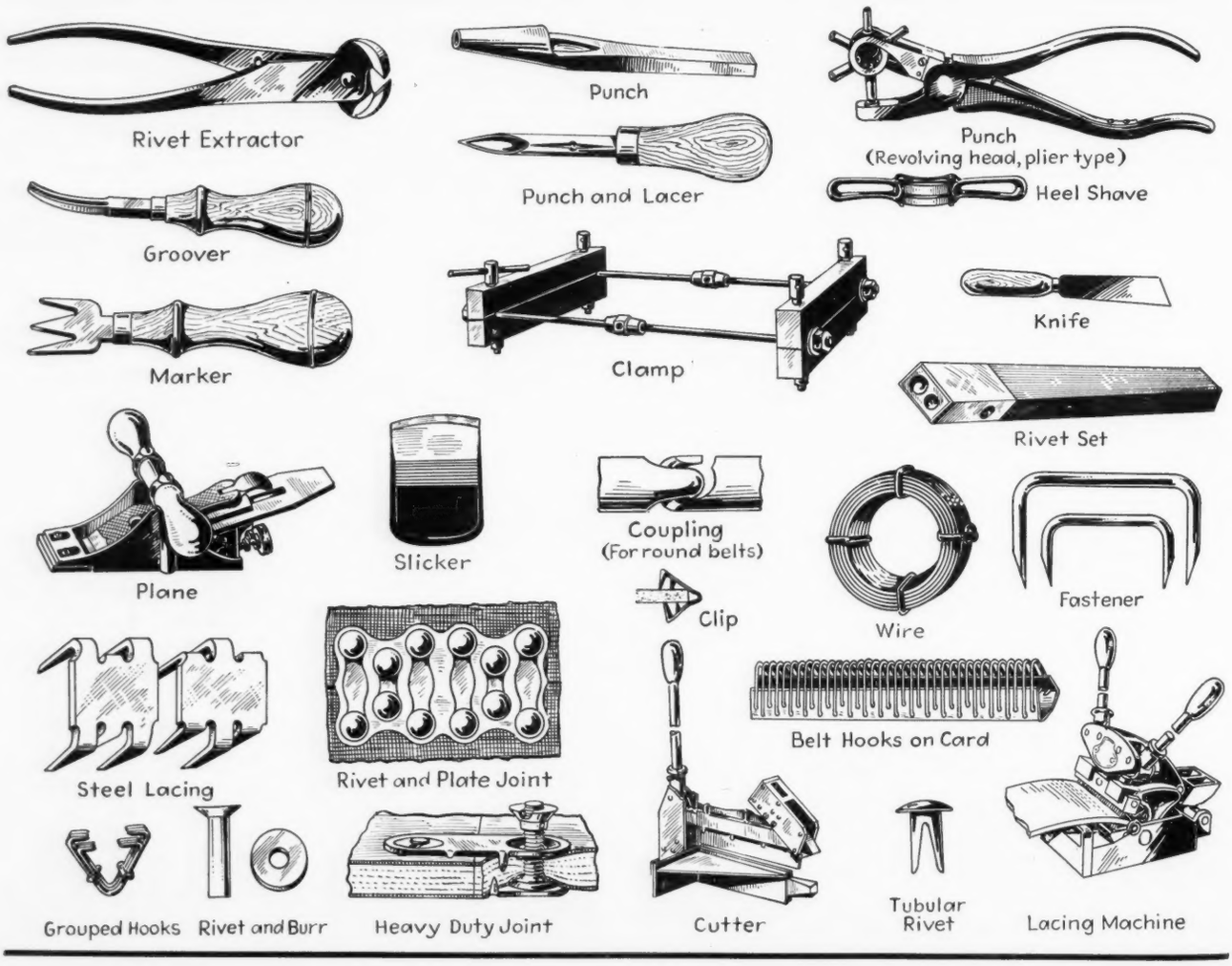
Tools for Belt Repair

FLAT BELTS can be joined by rawhide or wire lacing, riveting, hook fasteners, cementing or vulcanizing and various special patented fastenings. Emergency or normal field repairs require specialized tools, preferably kept in a kit that can be quickly taken to the belt as well as for use where the belt can be brought to the shop.

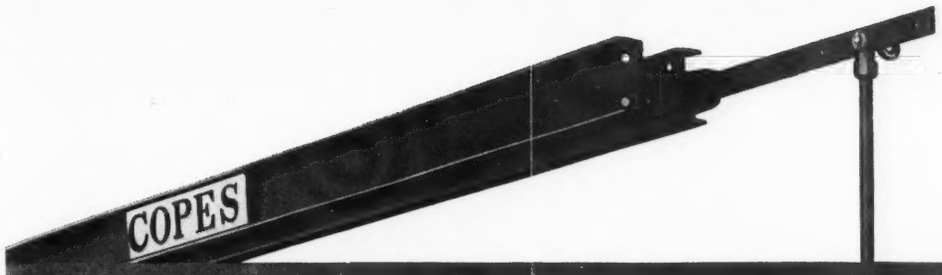
The standard kit of some years ago included a plier-type belt punch or several sizes of hand punch, a grooving tool, a marker, a square and either wire or rawhide laces. This equipment still suits small drive belts subject to sharp turns.

Cementing requires belt clamps, cement, a belt-maker's plane, a belt shave and a belt slicker. Of patented fasteners, commonest is the belt hook supplied mounted on cards, and requiring a machine clamping over each end of the belt; the through pin can be either rawhide or steel. Other fasteners, put across the joint, are driven through the belt ends and crimped.

Fabric belts are commonly fastened with riveted joint plates; these require a riveting hammer, bucking block and rivet extractor.



© POWER



14 COPES Flowmatics ordered by paper mill . . . to save $13,000 a year . . . to make boiler operation SAFER

To hold a safer water level on its seven power and seven recovery boilers, this paper mill has been supplementing its semi-automatic regulators with hand feed. Since the COPES Flowmatic would need no supplementary feeding, $13,000 could be saved each year by releasing water tenders for other duties—while the closer water level control made boiler operation safer.

You can profit from the closer, safer boiler water level control provided by the fully-automatic, trouble free COPES Flowmatic. Write for Bulletin 429, which describes this simplified two-element COPES Regulator.

NORTHERN EQUIPMENT CO., 1201 GROVE DRIVE, ERIE, PA.

Feed Water Regulators, Pump Governors, Differential Valves
Liquid Level Controls, Reducing Valves and Desuperheaters

★ GET CLOSER LEVEL CONTROL WITH THE COPES FLOWMATIC ★ REGULATOR

FEEDS BOILER ACCORDING TO STEAM FLOW-AUTOMATICALLY

ENGINEERS' BOOKSHELF

NEW TRENDS IN BOILER-FEED-WATER TREATMENT. *By Frederick G Straub, Research Associate Professor of Chemical Engineering, University of Illinois. Published by Engineering Experiment Station, University of Illinois, Urbana, Ill. Paper bound, 8 pages, price $.15.*—Reviews new trends in boiler-water treatment for prevention of scale, corrosion, embrittlement and carryover. These include latter developments in cold process softeners and the organolites of Zeo-Karb softeners. Newer types of steam purifiers described and discussion on corrosion in the "steam-blanketed" areas of boilers is presented.

ENGLISH ENGINEERING UNITS AND THEIR DIMENSIONS. *By E W Comings. Published by Engineering Experiment Station, University of Illinois, Urbana, Ill. 10 pages, paper bound, price $.15.*—System of units based on force pounds, mass pounds, feet and seconds is widely used in engineering. This is a four-unit system and requires the use of the dimensional constant which has the same numerical value as standard acceleration of gravity. Use of this dimensional constant is discussed and examples are worked out. Distinction between force pounds and mass pounds is made, together with an application of dimensional analysis.

SYNOPSIS OF BOILER LAWS, RULES AND REGULATIONS (1940). *Published by National Bureau of Casualty & Surety Underwriters, Boiler & Machinery Div, 60 John St, New York, N. Y. Price $.28 postpaid.*—Covers laws, rules and regulations relating to construction, installation and inspection of boilers and pressure vessels in the various states, provinces and cities of the United States and Canada. Briefly indicates standards of construction and relationship between legally constituted authorities, insurance companies and boiler manufacturers.

HOISTING AND PORTABLE ENGINEERS HANDBOOK. *By David J Newman Sr. Published by H & P Publishing Co, Station H, Buffalo, N. Y. 49 pages, paper bound. Price $2.00.*—Handbook contains 200 hoisting and erecting questions and answers, of which 147 are safety questions. Includes topics as boilers, brakes, signals, derricks, cranes, engines, platform hoists, pile drivers, and wire rope.

PHOTOELASTIC ANALYSIS OF TWO- AND THREE-DIMENSIONAL STRESS SYSTEMS. *By Bernard Fried and Royal Weller, Engineering Experiment Station, Ohio State University, Columbus, Ohio. 28 pages, graphs and illustrations. Paper bound, price $.40.*—Describes process of photoelastic analysis for studying stress concentrations in structures and machine parts. Includes the photoelastic method in two dimensions, tension specimen shape and apparent strength, photoelastic analysis of prestressed beam, and three-dimensional photoelasticity.

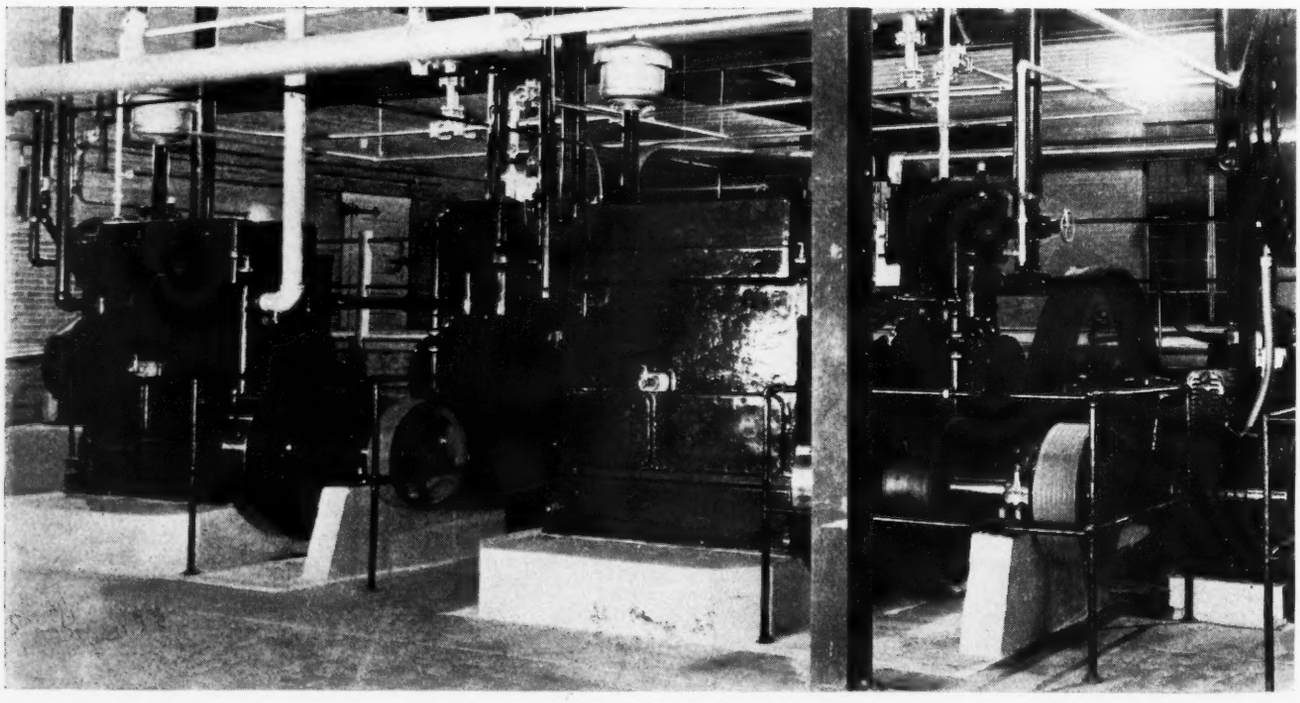
LEFAX DATA. *Lefax, Inc, Philadelphia, Pa.* Recent Lefax data received includes: No. 40-7 "Weldability of Metals by Electric Arc"; No. 31-115, "Fusion Welding of Aluminum"; No. 40-12, "Welding Requirements in Building Codes"; No. 33-12, "Cleaning Aluminum"; No. 14-79, "Lubricating Oil Tests"; No. 12-388 "Tables for Pipe Sizes"; No. 10-226, "Valve Timing"; No. 18-4 "Reistance Welding"; No. 8-85 "Electrical Precipitation"; and No. 30-2 "Conductivities of Building Materials and Insulators."

SUPPORTING STRENGTHS OF CAST-IRON PIPE FOR WATER AND GAS SERVICE. *By W J Schlick, Iowa Engineering Experiment Station, Iowa State College of Agriculture, Ames, Iowa, 128 pages, illustrations, graphs and charts, paper bound, available free if not out of print.*—Presents experimental results which, when combined with load calculation methods previously developed by station, provide convenient and reliable means for structural design of any line of cast-iron pipe subjected to both external load and internal pressure.

TESTING AND RATING CODE FOR LOW-

(*Continued on page 154*)

GAS MAKES ICE IN TEXAS



New streamlined gas engines drive ammonia compressors and auxiliary generators in Independent Ice & Refrigeration Co's modern plant at Abilene, Texas. Main units consist of two 96-hp, 3-cyl, 550-rpm Bruce-MacBeth engines in which the housing forms the cooling-water tank. All parts requiring cooling are submerged; supply pipes introduce water in volume required, overflow pipes maintain proper level. Compartment at front end of engine encloses governor, mixing valve and oil pump. The engines drive 9x9-in., 225-rpm Frick compressors through flat belts, and Electric Machinery Mfg Co "packaged" generators through V-belts

AGAIN - IT'S BALDWIN-HILL INSULATION

1300 hp. STEAM GENERATING UNIT in LARGE INDUSTRIAL PLANT

•

All Ducts and Breechings INSULATED with B-H BLANKETS and No. 1 INSULATING CEMENT

Here's a 1300 hp. steam generating unit operating at 700lb pressure. To provide maximum efficiency and insure added power output without increasing fuel costs, B-H Black Rockwool Blankets in thicknesses of 2", 2½" and 3", covered with ½" coat of B-H No. 1 Insulating Cement were used on ducts, breechings, induced draft fans, blowers and air heater casings. Low in calcium oxide content, B-H Black Rockwool Blanket is chemically stable—proof against excessive heat and moisture—and its soft, fine fibres have a resilience that insures against any settling action.

Behind Baldwin-Hill heat insulation products is an engineering staff that stands ready to co-operate with you in reducing heat losses and increasing the efficiency of your power plant equipment.

SEND FOR CATALOG for complete data on entire line showing applications, heat loss charts, insulating efficiencies, etc. on: B-H Black Rockwool Blanket . . . B-H No. 1 Insulating Cement . . . B-H Mono-Block . . , B-H No. 100 Pipe Covering . . . B-H Weatherseal . . . and other B-H insulating materials effective up to 2000° F.

See our Exhibit at the Power Show (Booth 224) Grand Central Palace, N. Y. City, Dec. 2-7.

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B-H

Sermons in Stones . . .

In October, I spent more than a half-hour out of a crowded day at the Metal Show watching an old glassblower and his wife. In that show were over 300 exhibits, showing the latest and best in metal-working equipment and materials —and there was I, watching a craft that was outmoded a hundred years ago!

But with me stood the largest crowd around any booth. The same thing happened at the glassblowing and blacksmithing exhibits at the New York World's Fair. People jammed every available nook and cranny to watch the old, while all around them was the ultra-new.

Of course some of the reason was that nostalgic longing we all get for the "good old days" and some was common curiosity. But beyond and above all that was the tribute all of us were paying to skilled men, our sincere admiration for people who can produce something beautiful with little more than their bare hands.

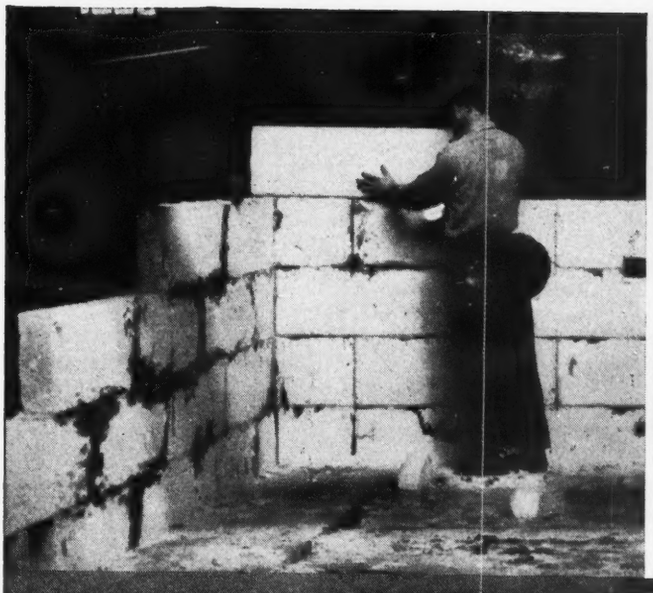
I honestly believe, too, that for most of us it wasn't wasted time. I know I learned some things about glass that I hadn't known, and I'll bet others did too. It didn't do any of us any immediate good, but we know something about glassblowing—just in case.

The "just in case" attitude is, I think, the right frame of mind in which to approach any exhibit. The Power Show in New York this month, for example, will include item after item that was scarcely more than thought of just a few years ago. They're new, up-to-date, and fashionable. But the Show will teach again many tried and true older ideas that can be applied just as successfully to our present-day problems. The smart thing for all of us to do under the circumstances is to collect ideas wherever we can get them.

The best reserve any chief can have is neither men nor capacity—it's the experience and knowledge to know what to do under any circumstances. That takes a constantly open mind, a continuing desire to learn whenever and wherever the opportunity presents itself. As Shakespeare said, there are "tongues in trees, books in the running brooks, sermons in stones, and good in everything."

George Edwards

Engineer



NOW! A NEW TYPE OF SUPEREX INSULATION!

Out of the J-M Laboratories comes this lighter, stronger, more efficient insulation for temperatures up to 1500° F.—L-W Superex

For temperatures to 600°, J-M 85% Magnesia; to 700°, J-M Asbesto-Sponge Felted; to 1900°, J-M Superex. This has been standard insulation practice in thousands of plants.

Now, for intermediate temperatures up to 1500°, the J-M Laboratories have developed a companion product for these outstanding insulations—the new L-W Superex. Within this temperature range, L-W Superex blocks and pipe insulation provide the durability and permanence so characteristic of all J-M Insulations, with the added advantages of light weight, high strength and increased insulating efficiency.

Between 1500° and 1900°, the former Superex, now known as H-T Superex, still remains No. 1 choice for reliability and maintained efficiency in service.

Detailed information on L-W Superex is now available in engineering data sheets. For your copies and facts on the complete line of J-M Insulations, just write Johns-Manville, 22 East 40th Street, New York, N. Y.

Johns-Manville INDUSTRIAL INSULATIONS

FOR EVERY TEMPERATURE . . . FOR EVERY SERVICE . . .

L-W Superex Blocks and Pipe Insulation . . . H-T Superex Blocks . . . Asbesto-Sponge Felted . . .
85% Magnesia . . . Sil-O-Cel C-22 Brick . . . Rock Cork . . . JM-20 Brick

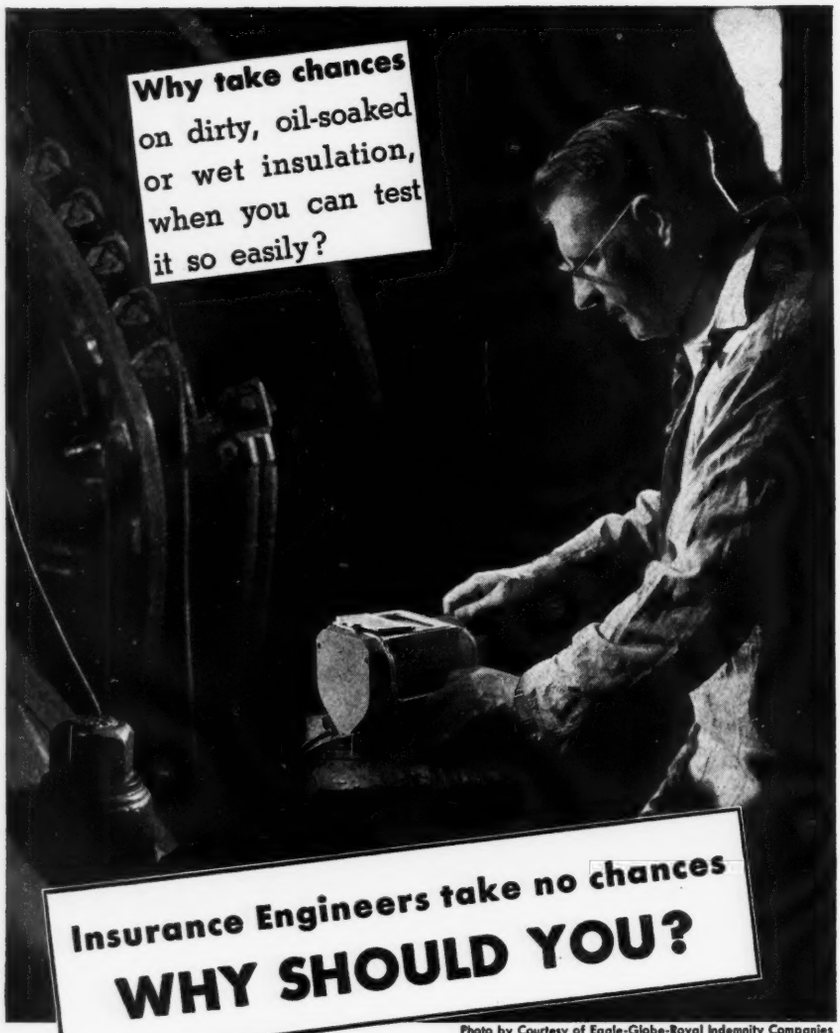


Photo by Courtesy of Eagle-Globe-Royal Indemnity Companies and Pennsylvania Sugar Company

When the engineers of the Eagle-Globe-Royal Indemnity Companies make a periodic inspection of electrical equipment which they insure, they take no chances on the insulation — they test it with a "Megger" Insulation Tester.

By this simple procedure and without risk of unnecessary breakdown, they penetrate unseen conditions caused by dirt, moisture and deterioration, and decide whether the insulation is in good or poor condition.

Hundreds of thousands of similar recorded tests made by leading Insurance Companies, as well as tests made independently by Operating Engineers, have shown that periodic insulation testing is an indispensable procedure for preventing unexpected electrical breakdowns and unnecessary outages and repairs.

Why take chances? Whether you carry electrical insurance or not, you want to avoid electrical breakdown. "Megger" testing is the practical way to go about it.

"MEGGER" TRADE MARK REGISTERED U.S. PAT. OFF.

Write for a copy of our Pocket Manual of "Megger" Practice, No. 1420-P.

James G. Biddle Co.

1211-13 ARCH STREET *Electrical and Scientific Instruments* PHILADELPHIA, PA.

Reader's Problems

(*Continued from page 111*)

As a secondary line of defense, I suggest treating with such chemicals as sodium sulphite, ferrous salts, tannin, etc, for removing last traces of dissolved oxygen.

New York, N. Y. L I PINCUS

Eight Years' Experience Shows Good Results

WE HAVE USED RAINWATER for the past eight years and find that we have had as good results or better than with well water. For about three years we used the rainwater just as it came from our concrete basin. We found that quite a large amount of dirt washed from the roof was pumped into the boilers, which required more frequent cleaning of the boilers.

Now, we pump all the rainwater through a filter and are having fine results. The filter has more than paid for itself in cutting down boiler cleanings and the use of rainwater has paid for the concrete basin because we save on water bills.

We treat this water for boiler feed and find it does not require as much treatment as city water.

Fostoria, Ohio WM H MCKEAN

Deaerating Heater Enough

I WOULD SAY that impurities picked up by the rainwater in passing over the roof and through the metal and sewer conductors would be negligible. The main trouble would be from gases absorbed from the atmosphere. If JW will treat his boiler feed by passing it through a deaerating heater and have all free gases removed, he can anticipate good results.

Toronto, Ont. J M FARRUGIA

Rainwater Purity Prevents Forming Protective Coating

A DISCUSSION OF THE SUITABILITY of rainwater for boiler-feed supply will probably be better understood if one realizes that (CO_2) and oxygen are prime factors of internal corrosion and pitting in steam boilers. Water has an affinity for both of these gases. Both are present in the atmosphere. Rainwater usually contains appreciable amounts of CO_2 and it may be saturated with oxygen when it is collected.

Frank N Speller states in his book "Corrosion—Causes and Prevention," that rainwater is characterized by absence of appreciable salt content and lack of ability to contribute to the formation of protective coatings. Salts in the water in appreciable amounts will, of course, cause undesirable scale formation. However, a "paper-thin" scale caused by slight concentration of solids in the water is often beneficial in forming a protective coating on the water

for every valve requirement

Standardize your power plant with valves bearing the time-honored name of Chapman — gate, globe, check and angle valves, manually or motor operated. You are then sure of more consistent performance through the uniformly high standards of Chapman precision workmanship.

Furthermore, in keeping the name the same—Chapman all the way—you never have to straddle a fence. For Chapman valves are available in a wide range of *Chapman-poured* metals and alloys, especially suited for specific services — from low pressure, low temperature, to 1000°F and 2500 lbs. pressure.

Our catalog will show you the right valve for the right job. Write for it.

(See our exhibits at the Show—Booths 46-47)

THE CHAPMAN VALVE MFG. CO. Indian Orchard, Mass.

MADE IN THESE ALLOYS

Carbon Steel—Carbon Molybdenum Steel —Chrome Nickel Steel—Nickel Steel— Chrome Molybdenum Steel

All poured into castings under the direct supervision of Chapman metallurgists, *right in Chapman's own foundry.*

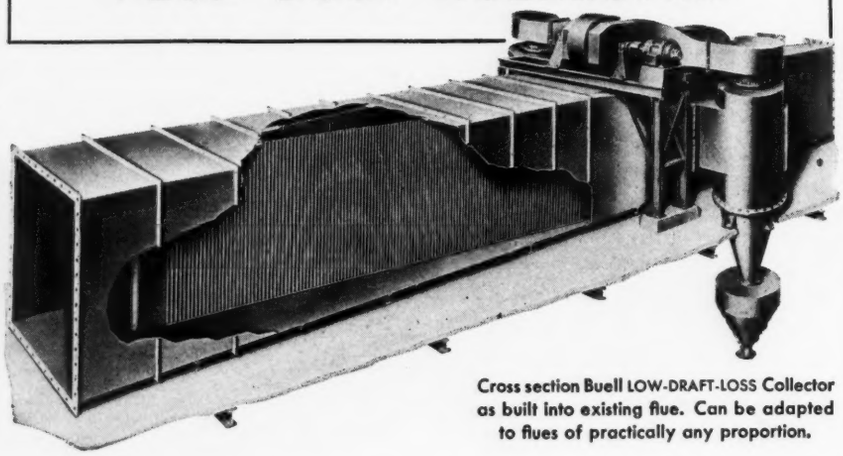
CHAPMAN POWER PLANT VALVES

A N N O U N C I N G

buell

Low-Draft-Loss

FLUE DUST COLLECTOR



Cross section Buell LOW-DRAFT-LOSS Collector as built into existing flue. Can be adapted to flues of practically any proportion.

Specifically designed for high collection efficiency at minimum power expenditure with stoker-fired boilers

Filling a long-felt need, the Buell (van Tongeren) LOW-DRAFT-LOSS Collector attains a high overall efficiency, with low draft loss, on extremely fine flue dust from stoker-fired boilers—*with the expenditure of only one horsepower for each 20,000 lbs. of gas per hour.*

The Buell LOW-DRAFT-LOSS Collector fits readily into existing ducts or, on new jobs, permits arrangement of flues without appreciable change in general plant layout. The Collector can be installed with boilers operating on natural draft. Where installed in front of induced draft fans, the erosive effect of flue dust on fan blades is practically eliminated.

A description of the Buell LOW-DRAFT-LOSS Flue Dust Collector as installed by one of the country's leading public utilities will be sent upon request.

BUELL ENGINEERING CO., Inc.
10 Cedar Street, New York

Offices of the Buell Engineering Company or B. F. Sturtevant Co. in principal cities are ready to serve you promptly wherever located.

surfaces. This coating may be so thin that its heat-insulating properties are negligible, and if it prevents direct contact between metal and water, corrosion may be minimized.

In the case of the plant referred to by JW, rainwater is collected from the roof and stored in underground concrete reservoirs. Here, the water may gain in acidity through contact with the concrete and by washing undesirable deposits from the roof. Soot, ash, tar, other carbonaceous products, sulphur oxides, and similar products may be deposited on the roof from discharge of chimneys and other industrial sources.

It would be possible to use the rainwater if a rather elaborate system of treatment were installed. It seems probable that the expense would be so high that water from other sources could be used with less essential treatment.

Canton, Mass. H M SPRING

Control Alkalinity, pH

THE GREATEST OBJECTION to rainwater as boiler feed is its strong corrosive action on ferrous metals. The process of natural evaporation and precipitation yields a water (rain) almost entirely free of dissolved solids. This lack of dissolved solids permits maximum absorption of gases such as oxygen and CO_2; the actual volume absorbed depends on temperature, relative pressure and purity of the air through which the rain falls.

Congested industrial districts show high CO_2 content. They will also contain frequently H_2S and SO_2, corrosive by nature. To overcome these, careful control must be maintained over boiler-water alkalinity and pH concentration.

Some suspended matter will be picked up from the atmosphere and some solids will be dissolved during the rain's passage from the slate roof to the underground concrete storage tank and thence to the boiler. Small amounts of silica and lime will be picked up in the storage tank. However, suspended and dissolved solids do not present a serious problem and they can be controlled by properly balanced treatment.

New York, N. Y. LLOYD M POTTS

Power Lines

(*Continued from page 124*)

mer comes from Keuffel and Esser, where Mary Pfeiffer has been collecting it for 51 years. She is a one-woman industry. Men don't have the nimbleness of finger necessary to pick up the gossamer as a spider spins it, and no other woman has ever been found with the nerve to handle spiders. So Mary Pfeiffer lets her spiders out every day and reels up the gossamer they spin—some 2000 feet a year!

OBITUARIES

JOHN CALLAHAN, 66, former professional baseball player and from 1911 to 1936 supervising engineer of the Jersey City,

Boiler Protection for "Accuracy Headquarters"

Pratt & Whitney install a Cochrane 100,000 lb./hr. Deaerating Heater

WHEN Pratt & Whitney, Division of Niles-Bement-Pond Co., whose slogan is "Accuracy Headquarters," put up a new plant at West Hartford, Conn., they installed a Cochrane Deaerating Heater of 100,000 lb./hr. capacity in the boiler plant. This heater is of cast iron rectangular construction with caulked joints. It is designed for 85% condensate returns at 180° and 15% makeup at 50°. Condensate is supplied from an overhead storage tank. For emergency makeup, a float-controlled pilot-actuated regulating valve at the low level admits makeup from the city mains. A Cochrane electric telemetering unit is installed in the weir chamber connecting with a Cochrane flow meter on the boiler instrument panel.

Thus another great plant, indispensable in America's defense program, safeguards its power needs with Cochrane equipment.

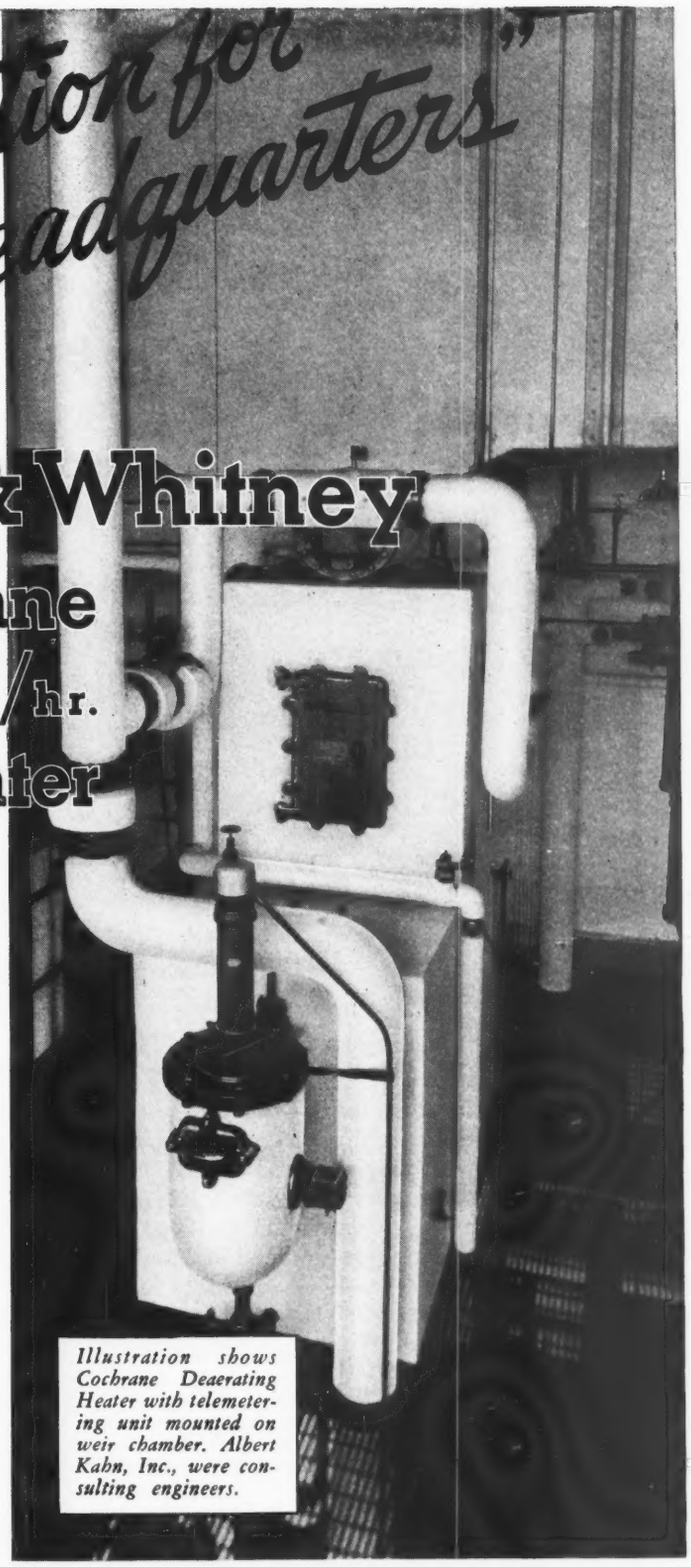


Illustration shows Cochrane Deaerating Heater with telemetering unit mounted on weir chamber. Albert Kahn, Inc., were consulting engineers.

COCHRANE CORPORATION • 3106 N. 17th St., PHILADELPHIA, PA.

COCHRANE

WATER SOFTENERS • DEAERATING HEATERS • DEAERATORS • BLOW-OFF EQUIPMENT • VALVES • FLOW METERS

DELIVER AIR AT LOW COST where you need it

You save money by installing SCHRAMM air compressors.

These modern units—correctly engineered and designed for high efficiency and low power consumption—can be placed in any convenient location. Vertical cylinders, cast enbloc, insure a compact design using a minimum of floor space. Perfect balance eliminates the need for special foundations. Ability to install the unit close to the point where air is needed, reduces piping costs. Integral cooling saves water and insures uniform temperature for proper lubrication.

See Our Exhibit at Booth 481-482
NATIONAL EXPOSITION OF POWER AND MECHANICAL ENGINEERING
GRAND CENTRAL PALACE
NEW YORK • DEC. 2-7, 1940

Schramm Inc., West Chester, Pa.

SCHRAMM COMPRESSORS

N. J., public school system, died of a heart ailment October 29. He played baseball in his youth with the New England State League and later with semi-professional teams in New Jersey. He joined the school system as engineer of a public school, No. 20, in 1901. He was state president four times and national president once, of the National Association of Power Engineers, and was active in obtaining legislation controlling the licensing of stationary engineers.

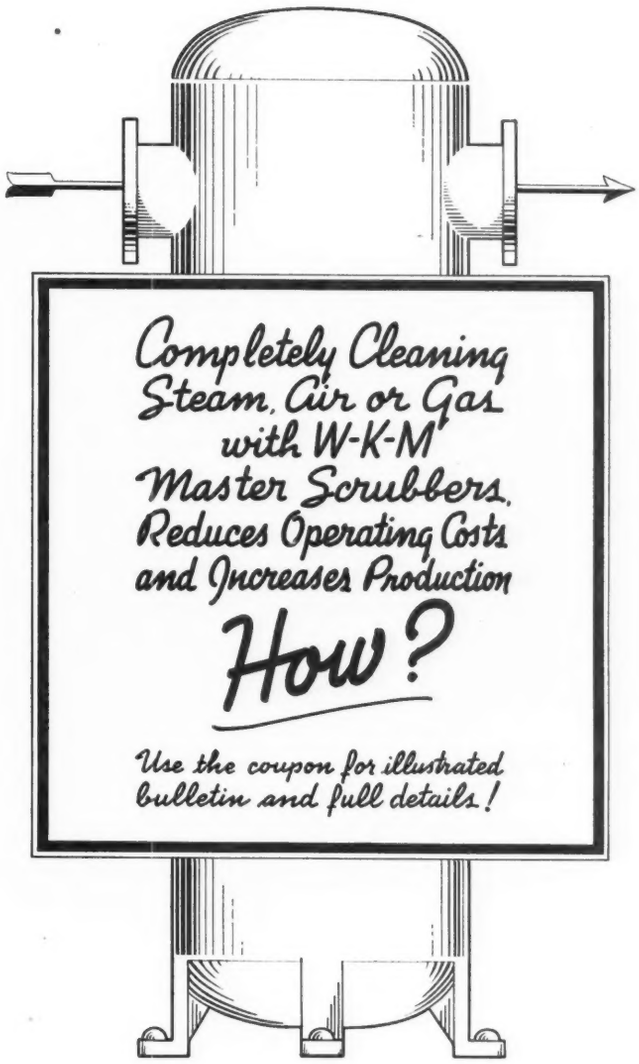
JAMES J GILLIS, 78, former operator at the power plant of the Rochester Gas & Electric Corp, Mt Morris, N. Y., died recently at his home there. He had retired from his position several years ago with a pension.

ARTHUR W EDWARDS, secretary of the Sterling Blower Co, and the Hartford Blower Co, died October 23 at his home in Hartford, Conn., after short illness. He was a native of Wilkes-Barre, Pa., and had resided in Hartford 38 years.

GILBERT A DURANT, 71, for 46 years chief engineer at the Groton School, died October 22 at his home in Groton, Mass. He was a native of South Hero, Vt.

GEORGE B CORTELYOU, 78, retired president of the Consolidated Edison Co of New York, died suddenly at his home at Huntington, L. I. He was the fourth president of the Consolidated Gas Co (now Consolidated Edison) and retired on July 1, 1935. He had joined the company in March 1909 as president and trustee, just after he had left his position as Secretary of the Treasury in President Theodore Roosevelt's cabinet. Mr Cortelyou was born in New York City and attended public schools there. He was graduated from the Hempstead, L. I., Institute in 1879 and from State Normal School, Westfield, Mass., in 1882. He had a varied career in Washington, serving three cabinet positions, and was the personal friend of three presidents. In 1918 he became the first president of the American Gas Assn, serving two terms, and in 1932 was elected president of the National Electric Light Assn. He had served as a director of the New York Life Insurance Co since 1914, and was a director of D Appleton-Century Co. Mr Cortelyou was also on the executive board of other organizations, and was an officer or director of most of the companies in the Consolidated Edison System.

H H TIMKEN, SR, chairman of the board of the Timken Roller Bearing Co, died Monday, Oct 14, at his home in Canton, Ohio, following an attack of pneumonia. He attended St. Louis, Mo., High School, and was graduated from there as an honor student. Following his graduation he attended the University of California and received his law degree there. When his father re-entered the carriage and wagon-making field at St Louis, he gave up law and joined him in business. Shortly afterwards his father perfected the principle of the Timken tapered roller bearing, and within short time bearing and axles formed the largest part of Timken production. Anticipating the time when the bearings would be used in automobiles, the company moved to its present location, Canton, Ohio,



Completely Cleaning Steam, Air or Gas with W-K-M Master Scrubbers, Reduces Operating Costs and Increases Production

How?

Use the coupon for illustrated bulletin and full details!

BRADSHAW & CO., 530 Fourth Ave., Pittsburgh, Pa.

Gentlemen: Without obligation, you may send me the bulletin fully describing the W-K-M Master Scrubber for:

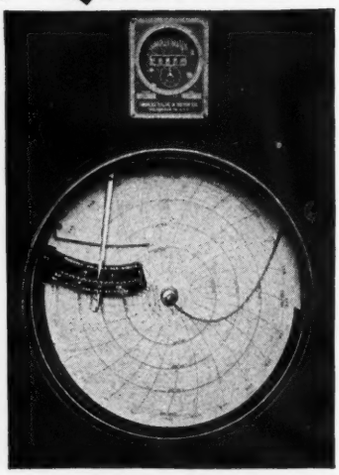
STEAM ____ AIR ____ GAS ____

Name ____ Company ____ Address ____ City ____ State ____

(PLEASE PRINT)

Gives QUICK Answers To ALL Flow Questions

How much hot water is going into steam? . . . Are boilers working at top efficiency? . . . How much gas are we using each day? . . . Let a Simplex Meter give you the quick, accurate answers to these important plant flow questions.

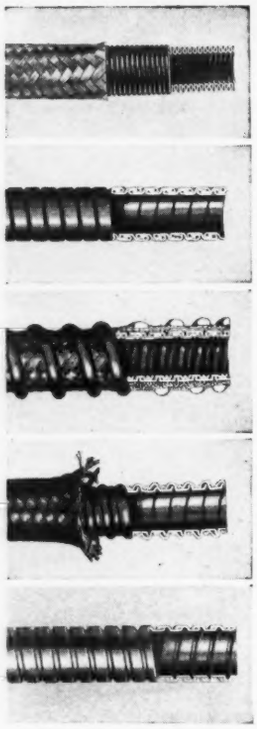


TYPE M S METER

Simplex Meters can be used with any type of pressure producing device (orifice, nozzle, venturi tube) in any size of main to totalize the flow of Boiler Feed Condensate, Steam, Air, Gases and Corrosive Liquors. It is extremely accurate and reliable over wide ranges. And its modern price puts it within easy reach of every plant. Write for new descriptive bulletin.

SIMPLEX VALVE & METER CO.
6780 UPLAND ST., PHILADELPHIA, PA.

NEW BULLETINS POINT WAY To Trouble-free Service with FLEXIBLE Pipe



1 PENFLEX-WELD is the new corrugated jointless tubing for all services where leaks are fatal. In steel or bronze. See Bulletin 90.

2 PENFLEX 4-WALL INTERLOCKED, pioneer of flexible safety, described in Bulletins 52 and 59. Tank Car, Bulletin 55; and Marine, Bulletin 58.

3 PENFLEX HIGH RIDGE is a medium duty type offering many possibilities to ingenious designers: Bulletins 52 and 59.

4 PENFLEX EXTRA-FLEX has greatest flexibility consistent with safety: Write for Bulletins 52 and 59.

5 PENFLEX LIGHTWEIGHT is widely used for conduits, conveying light material, vent ducts, spouts, etc. Bulletin 60.

PENFLEX

Tight as Pipe . . . but Flexible

Pennsylvania Flexible Metallic Tubing Co.
7202 Powers Lane, Philadelphia, Pa.

in 1901, and production was started in 1902. Mr Timken then became active head of the plant. As the factory expanded, he took less active part in the factory management and devoted more of his time to supervision of the entire plant. Although still active in the business at the time of his death, he had been turning over the actual management to his two sons, H H Timken, Jr, and W Robert Timken.

WILLIAM V DINSMORE, 68, for 33 years stationary engineer at Public School 7 in Buffalo, N. Y., died October 20 from injuries suffered in an automobile accident the night before.

CLAUDE L FARIS, chief operator of the Sherman, Vermont, hydroelectric station on New England Power Association System, died recently at his home in Monroe Bridge, Vt. He entered the service of the system in 1926, and was placed in charge of the Sherman plant in 1933.

PAUL M MACKLIN, of New York, vice-president and general manager of Wickwire Spencer Steel Corp, was drowned with two companions, Nov. 6, while hunting in Maine. Other victims were George W Nelson, superintendent of the Buffalo plant of the corporation, and Mr Macklin's son, John, foreman at the same plant.

PERSONALS

FRED ELWELL, superintendent of all power plants of the British Columbia Electric Railway Co, Vancouver, B. C., has now retired. Mr Elwell came to B.C. Electric in 1911 from West Kootenay Power & Light Co, where he had been superintendent of power plants at Bonnington Falls, B. C. After spending 13 years as senior engineer at the Lake Buntzen power plants, he was made superintendent of all plants on lower Mainland territory.

THOMAS INGLEDOW has joined British Columbia Electric Railway Co as chief engineer. He was formerly associated with the Montreal Light Heat and Power Co,

MEETINGS

American Institute of Chemical Engineers —*33rd Annual Meeting, December 2–4, St. Charles Hotel, New Orleans, La.*

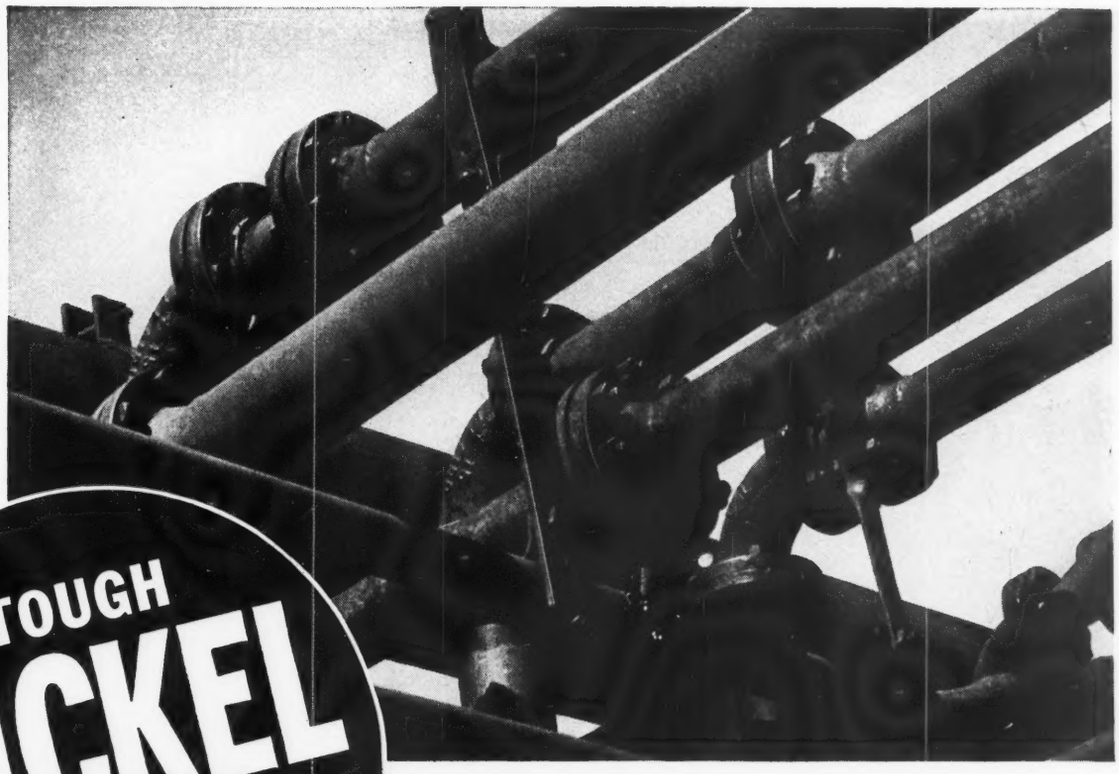
American Institute of Electrical Engineers —*Winter Convention, January 27–31, 1941, Bellevue-Stratford Hotel, Philadelphia, Pa. H H Henline, secretary, 29 W 39 St, New York, N. Y.*

American Society of Heating and Ventilating Engineers—*47th Annual Meeting, January 27–29, 1941, Hotel Muehlebach, Kansas City, Mo. A V Hutchinson, secretary, 51 Madison Ave, New York, N. Y.*

American Society of Refrigerating Engineers—*36th Annual Meeting, December 4–6, Hotel Commodore, New York, N. Y. David L Fiske, secretary, 37 W 39 St, New York, N. Y.*

American Society of Mechanical Engineers *61st Annual Meeting, December 2–5, 1940, Hotel Astor, New York, N. Y. C E Davies, secretary, 29 W 39 St, New York, N. Y.*

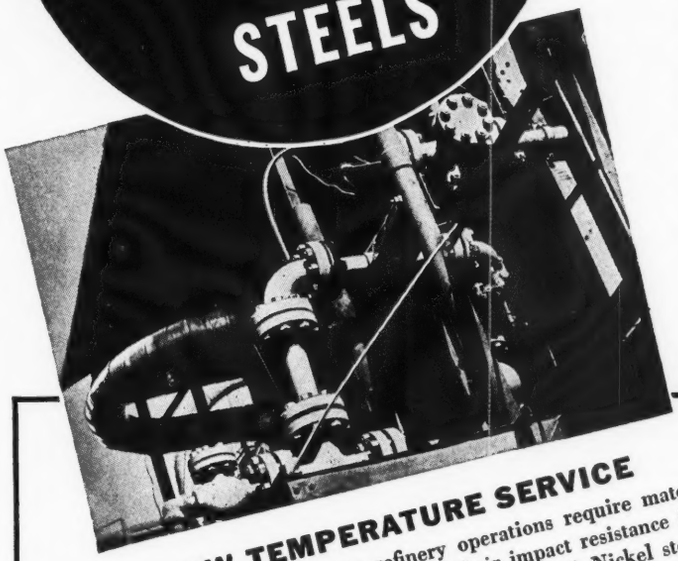
New York Power Show — *Grand Central Palace, New York, N. Y., December 2–7, 1940. Management, International Exposition Co, New York, N. Y.*



TOUGH NICKEL ALLOY STEELS

HIGH TEMPERATURE SERVICE

When refinery lines are running at high temperatures, leakage or failure of a pipe joint may be the forerunner of disaster—loss of property and even life. Hence, refinery bolts must be made of sure, dependable materials—capable of withstanding severe mechanical stresses as well as the thermal and pressure extremes encountered when the lines are running hot in operation. Strong, tough, stress-resisting Nickel alloy steels SAE 4340 and SAE 3140 are widely used for this vital application as evidenced by these two scenes in a large Mid-Continent refinery where bolts of the latter Nickel alloy steel, manufactured by the St. Louis Screw & Bolt Co., are rendering long, safe service, minimizing the danger of leakage and failure.



LOW TEMPERATURE SERVICE

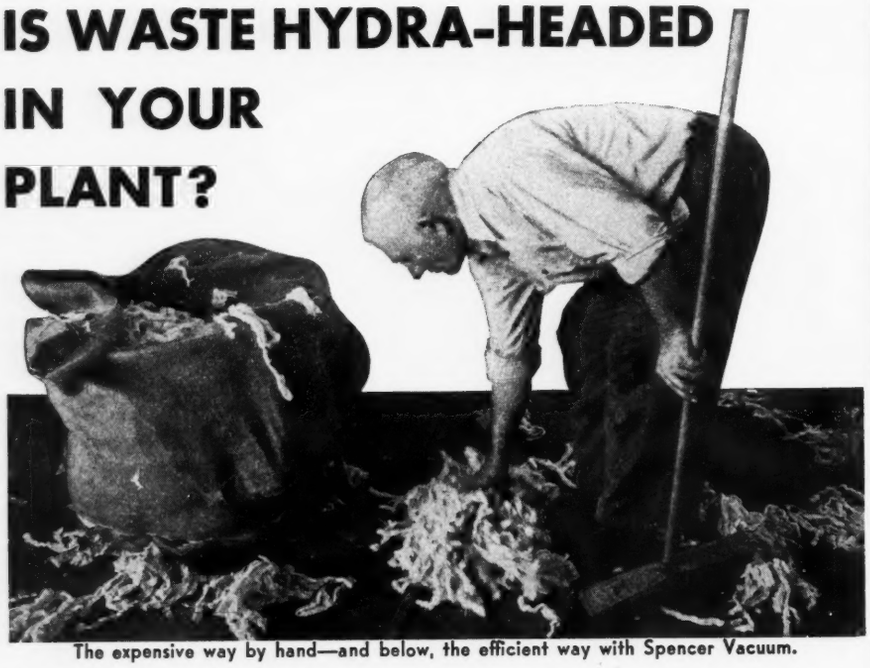
Sub-zero temperatures in refinery operations require materials which stay tough and retain their impact resistance in extremely cold zones. Bolts of SAE 2315 3½% Nickel steel resist low temperature embrittlement and provide requisite physical properties. Tough, dependable, long-lasting Nickel alloy steels are also widely used for other refinery applications including exchangers, condensers, coolers, valve bodies, pressure vessels, return bends, tube supports and dewaxers.

BOLTS THAT STAY TOUGH AT HIGH AND LOW TEMPERATURES

CONSULTATION is invited regarding Nickel alloy steels which assure a safe margin of strength and toughness at both elevated and sub-zero temperatures.

THE INTERNATIONAL NICKEL COMPANY, INC. 67 WALL STREET NEW YORK, N. Y.

IS WASTE HYDRA-HEADED IN YOUR PLANT?



The expensive way by hand—and below, the efficient way with Spencer Vacuum.

In figuring manufacturing costs, wastage is calculated in pounds or feet or in percentage of the original material cost. But that's only half the story. In most cases it costs more to clean up waste than the material was originally worth. Furthermore, if not cleaned up frequently, waste slows up production and gets kicked around, creating dust which is spread all over the plant.

SPENCER VACUUM CLEANING in industry can reduce the cost of cleaning and practically eliminate the other profit consuming losses of this hydra-headed monster which may be eating up as much as 5% of the cost of your finished product.

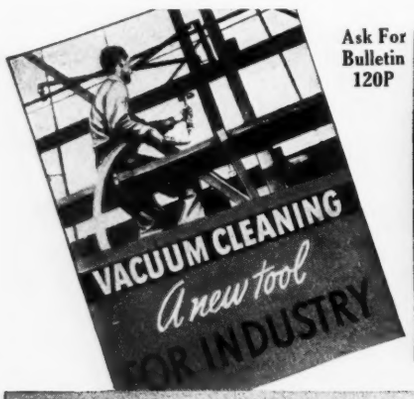
Spencer Vacuum is saving up to 25% of the time and cost of cleaning factory floors. It cleans walls, ceilings, pipes, and machinery with amazing rapidity and without distributing any dust.

It reduces fire, health and explosion hazards, reclaims valuable materials, reduces rejects, and cleans products during and after production. It saves in three or more of these ways in each plant according to a survey of 444 users, many of whom have enjoyed the benefits of a Spencer for a quarter of a century or more.

BUILT IN SIZES FOR ALL PURPOSES

Spencer Systems for industry vary in size from a ¾ HP portable to 100 HP stationary systems with inlet valves on each floor.

The new Spencer 7½ HP portable with a dirt capacity of 7½ cubic feet, for instance, may be just the thing to meet your requirements.



Ask For Bulletin 120P

182-E

SPENCER HARTFORD

CENTRAL AND PORTABLE VACUUM CLEANING SYSTEMS

THE SPENCER TURBINE COMPANY, HARTFORD, CONN.

where he was assistant engineer, electrical department. He came to Canada several years ago, following his graduation from Glasgow University and London University in England. He started as an electrical designer with the Ontario Hydroelectric Power Commission at Toronto, later joining Stone & Webster, Inc, in Boston, Mass. In 1925 he went to the Montreal utility and remained there until his present position.

J P Fraser has been appointed superintendent of hydroelectric plants by British Columbia Electric Railway Co. Born in Manitoba, Mr Fraser was graduated from the University of Manitoba in electrical engineering. After the first World War he joined the Canadian Westinghouse Co. He was appointed engineer in charge of construction of electrical features of the Seven Sisters plant of Winnipeg Electric Co, and then went to the Manitoba Power Commission as general superintendent and chief engineer. Mr Fraser held that position until his resignation to accept his present opening.

F L Curtis, treasurer of Raybestos-Manhattan, Inc, and general manager of the Rubber Mfg Div, was elected a director in the Rubber Manufacturer's Assn at the annual meeting held October 17 in New York. His term will expire in 1941.

S J Horrell has been appointed vice president of Power Piping Div, Blaw-Knox Co. Mr Horrell joined the company in May, 1939, and has been serving this division in capacity of sales manager. His duties have been increased to include charge of engineering and sales. Harry Gay has been engaged by the company and has been appointed chief engineer of the Power Piping Div.

William B Ramsdale has been named to the technical staff of Battelle Memorial Institute, Columbus, Ohio. He is a graduate of Southwestern College and Syracuse University. Mr Ramsdale will investigate ignition temperatures of various coals and cokes.

W M Black has been appointed president of the American Manganese Steel Div, American Brake Shoe & Foundry. He became general sales manager of this division in 1934 and vice-president in 1935. He has been with "Amsco" since 1912, with the exception of the war years, when he served in the U. S. Ordnance Dept.

J O Henkle, Jr, manager of the Huntsville, Ala., municipal power system with TVA power, resigned recently. He will resume his previous connection with the Alabama Power Co.

George Bigelow, formerly president and general manager of Pacific Pump Works, is now head of Universal Television Co. Mr Bigelow organized the Pacific Pump Works in 1923 and many of the early patents on centrifugal pumps were taken out in his name.

Marcus Hemmens, stationary engineer at the Central YWCA in Buffalo, N. Y., for more than 30 years, and Mrs. Hemmens

FAIRBANKS

PLUG TYPE VALVES

If you're having trouble keeping valves tight at points where the service is unusually hard, such as for throttling, blow-off, boiler feed or in drain and drip lines, Fairbanks Plug Valves will solve your problem.

Seats and discs are made of a special nickel alloy of high Brinell hardness that resists erosion and will not seize or gall.

The wide sealing surface in the seat and disc and the angle of the plug, distribute the stream flow so that it is never concentrated in one position, giving further protection against galling and wire drawing. The plug is ground into its own seat to insure a perfect fit.

Should these parts become worn, they can be replaced easily and quickly, or reground without removing the body from the pipe line.

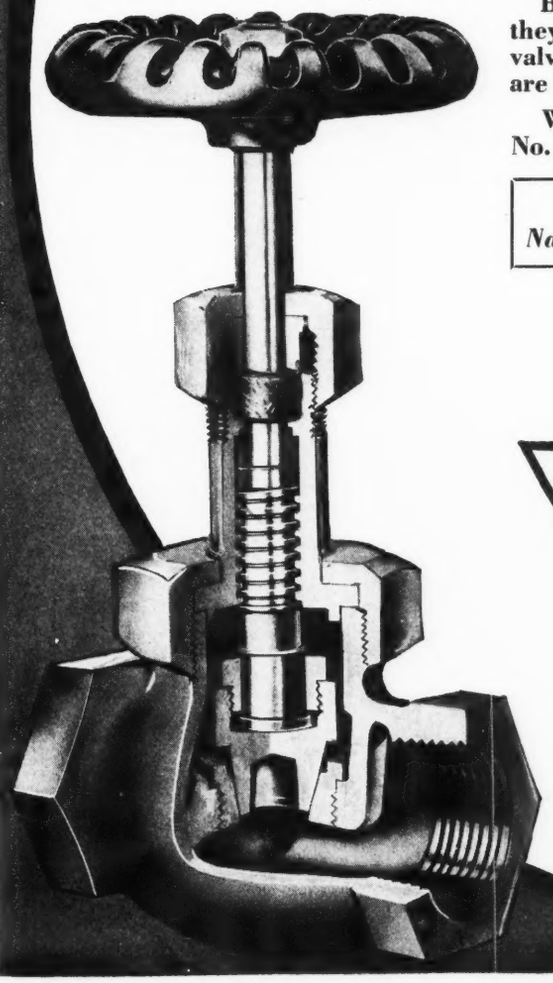


Fig. 0501-P

Because of their rugged construction and the fact that they will withstand steam pressures up to 225 lbs., these valves can be safely used for most installations, yet they are comparable in price to standard regrinding types.

Write for name of our nearest distributor and catalog No. 21, or mail the coupon.

See our exhibit at booth 78
Nat'l Exposition of Power & Mechanical Eng., Dec. 2–7

THE FAIRBANKS COMPANY
397 Lafayette St., New York, N. Y.
Valves, Dart Unions, Hand Trucks and Wheelbarrows
Boston, Pittsburgh—Distributors in Principal Cities
Factories: Binghamton, N. Y., Rome, Ga.

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Without obligation, kindly send a copy of your valve book No. 21

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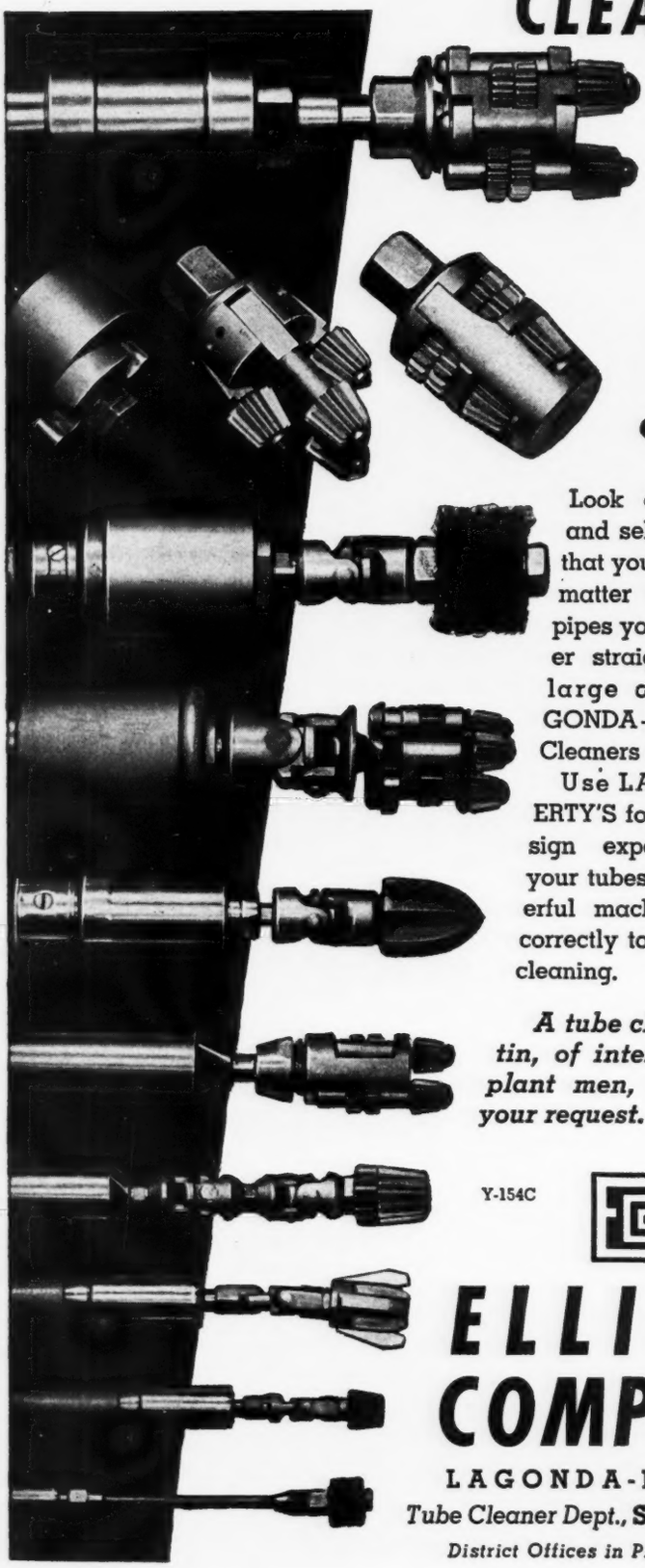
ADVERTISING PAGES REMOVED

Clean any tube with **LAGONDA LIBERTY CLEANERS**



Look down the line and select the cleaner that your job needs! No matter what tubes or pipes you have—whether straight or curved, large or small—LAGONDA-LIBERTY Tube Cleaners can clean them. Use LAGONDA-LIBERTY'S forty years of design experience. Clean your tubes with fast, powerful machines equipped correctly to do your job of cleaning.

A tube cleaning bulletin, of interest to power plant men, is ready for your request.

Y-154C

ELLIOTT COMPANY

LAGONDA-LIBERTY

Tube Cleaner Dept., **SPRINGFIELD, O.**

District Offices in Principal Cities

celebrated their golden wedding anniversary October 20.

S N F Hedman, formerly a member of the Turbine-Design Department of General Electric Co, River Works, Lynn, Mass., has been appointed assistant design engineer of the mechanical drive section of the Turbine Department of same plant. He was graduated in electrical engineering from the University of New Hampshire in 1925 after starting with the company as student engineer in the Compressor-Engineering Dept. In 1934 he was transferred to the mechanical drive section of the Turbine Dept.

Harold B Thomas, one of the founders of Elastic Stop Nut Corp, Union, N. J., and vice-president in charge of sales, has resigned to enter consulting work in industrial product analysis and market research. He remains active as a director and member of the executive committee of the corporation.

George W Curtis has been appointed Milwaukee Division manager of Timken Roller Bearing Co. Since his graduation in 1920 from Carnegie Institute of Technology he has served in engineering and sales capacities at Canton, O., and Pittsburgh, Pa. He was transferred from Pittsburgh to Milwaukee in 1930.

George A Orrok, well-known consulting engineer and member of the engineering firm of Orrok, Myers & Shoudy, New York, sailed for Panama on October 24. Mr. Orrok will serve as consultant on new construction operations at the Canal.

D C Peterson, formerly vice-president in charge of manufacture of the Buda Co, has been appointed works manager of the Superior Engine Div, National Supply Co. He joined the Buda Co. in 1915, and after several years with that company, left to assume responsibilities with Continental Can Co. Mr Peterson rejoined the Buda Co in 1939 as vice-president in charge of manufacture and had during the past year constructed and placed in operation two plants for manufacture of radial diesel engines.

W T Roundy has been transferred to the Atlanta office of Cutler-Hammer, Inc. Mr Roundy has been assigned to the state of Florida and will make his headquarters in Orlando.

Earl N Graf, former manager of Pittsburgh Branch of John A Roebling's Sons Co, has been appointed assistant manager of sales, Wire Rope Div, with headquarters at Trenton. He was manager of the Pittsburgh office since 1939, having joined that office in 1938.

BUSINESS ITEMS

General Electric Co will open its Jackson Lamp Works, a new subsidiary of that company, at Jackson, Miss., Dec. 1. Z B Taylor is an executive of the company, which will make fluorescent lighting equipment.

Rx for Superior Packing Performance against Steam

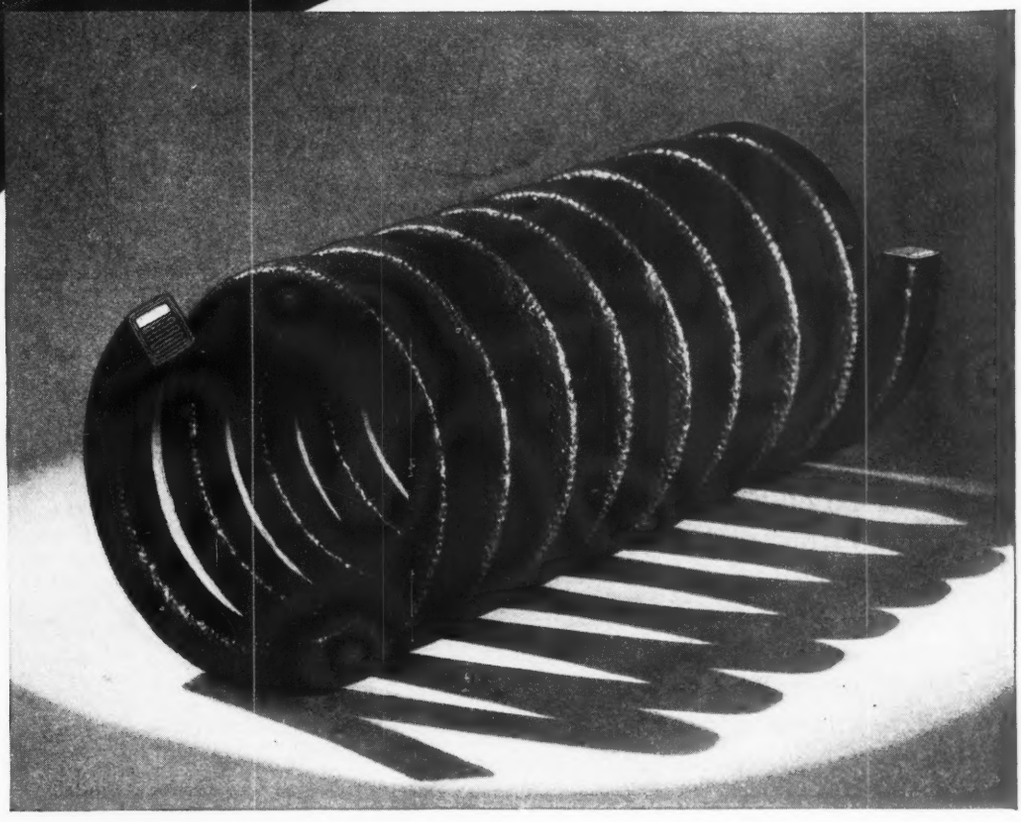


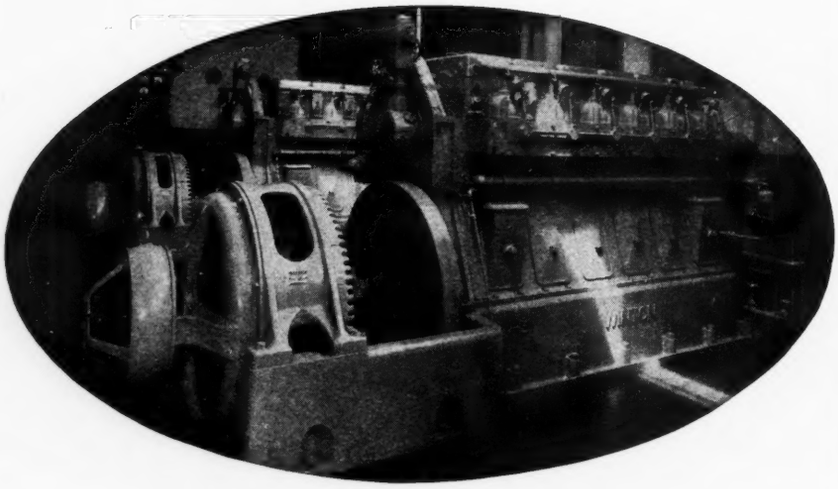
Illustration shows GARLOCK 150 spiral. If coil form is desired—specify GARLOCK 125. If cut rings are desired—specify GARLOCK 200.

WHY do so many thousands of engineers "prescribe" GARLOCK 150 High Pressure Packing—consistently year after year? Because they know from experience that GARLOCK 150 is *tough, strong, dependable.* They know it prevents costly shut-downs for frequent repacking. They know it saves money. For superior performance on piston rods of engines, pumps, compressors, expansion joints, etc., against steam pressures up to 300 lbs., standardize on GARLOCK 150.

THE GARLOCK PACKING CO., PALMYRA, N. Y.
In Canada: The Garlock Packing Co. of Canada Ltd., Montreal, Que.

GARLOCK 150

SERVICE PROVED Lubricants Assure Dependable Performance



Trick oils may look impressive in short demonstrations, but if you want Diesel oils that will give dependable, consistent performance — every day — every week — every month — you will want an oil that has proved its worth. Not an experimental oil but one that has been service proved — a Cities Service oil, engineered for the job.

Experience has shown that no one oil will prove most effective and economical for a given make of engine under all conditions of operation. Such factors as power output, crankcase oil temperatures, etc., may as often as not make the use of a cheap oil expensive and an expensive oil cheap. Let one of our lubrication engineers tell you why — and prove it on your own equipment. Mail the coupon to us or write us on your own letterhead.

In any event you will benefit from reading a copy of our new booklet on "Diesel Engine Lubrication." Sent free to any user of Diesel engine oil.

CITIES SERVICE DIESEL LUBRICANTS

CITIES SERVICE OIL CO.
SIXTY WALL TOWER—Room 1626A,
NEW YORK, N. Y.

Please send me information concerning your Engineers' Lubrication Service (check box) ☐

Please send me folder on "Diesel Engine Lubrication" .....(check box) ☐

*Name*_____

*Firm Name*_____

*Address*_____ *City*_____

D W HAERING & Co, Chicago, Ill., has added several chemists and engineers to augment its present staff. George Thompson, formerly at the Chicago Laboratory, was promoted to the New York district. Douglas M Considine, chemical engineer, was added to the staff of the Chicago Lab, and the Wichita Lab has added the services of O R Borngesser. J R Lindley and D R Walser have been added to the Chicago sales organization, and F H Wright of the Chicago staff was promoted to the Chicago District Service Dept. Ernest F Kling and Joseph Babush were placed in charge of the Detroit and Milwaukee offices, respectively.

GUSTAVO PRESTON Co, 113 Broad St., Boston, Mass., has been appointed representative of Yeomans Brothers Co, Chicago, pump manufacturers.

MCCLAVE-BROOKS Co, manufacturers of stokers and grates, has been reorganized to the McClave Co, with main offices and works at 936 Hamilton St, Allentown, Pa. Company has appointed J Beggs & Co, 92 Liberty St, as New York representative; J E Rushmore, in the Scranton area.

WARD LEONARD ELECTRIC Co announces opening of a branch office in Rochester, N. Y. New office, located in Lincoln Alliance Bank Bldg, will be managed by J K Savage, sales engineer.

DRESSER MFG Co announces purchase of Pacific Pump Co, Huntington Park, Calif. J B O'Connor, vice-president of Clark Bros Co, Olean, N. Y., another subsidiary of Dresser, will serve as chairman of the board of directors. A R Weis, formerly vice-president of Pacific Pump, was elected president of the California company and R E Reimer, treasurer of Dresser, has been named secretary. A R Weis is president of the companies.

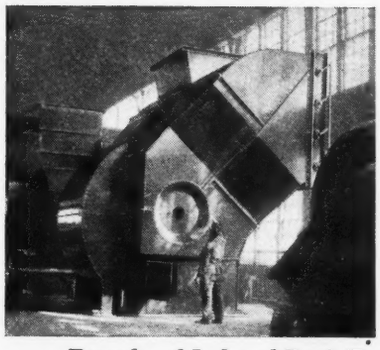
D W HAERING & Co, INC, Chicago, Ill., plans addition to supplement present manufacturing facilities. A new plant will be constructed on the Texas Gulf Coast Area, for converting of raw materials into intermediate and finished products. West Coast will be served by a new laboratory to be established early in 1941 at Los Angeles or San Francisco.

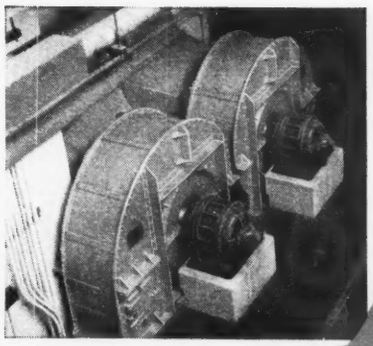
WORTHINGTON PUMP & MACHINERY CORP, Buffalo, N. Y., plant, is now operating on 24-hr schedule with 1,500 men on the payroll. Work is being done on diesel and other engines for power-plant equipment in national defense industries.

New address of A EUGENE MICHEL & STAFF, INC, advertising agency, is 2 Park Avenue, New York, N. Y., effective November 4, 1940.

CUTLER-HAMMER, INC, Milwaukee, announce opening of new factory, warehouse, and sales office in San Francisco, Calif. This will be located at 711 Potrero Ave. Building also includes large warehouse space with facilities for stocking and handling company's line of electrical control apparatus.

SPRAYING SYSTEMS Co, Chicago, Ill., announces appointment of F R Magill,





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Custom built for every mechanical draft service. All types of volume control. Efficient, dependable, durable, economical.

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Increased Boiler Capacity *and* Lower Steam Costs

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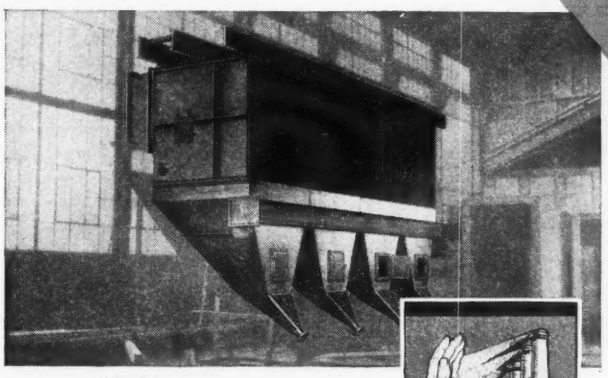
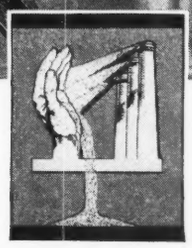
THE GREEN *Fuel Economizer* COMPANY INC.

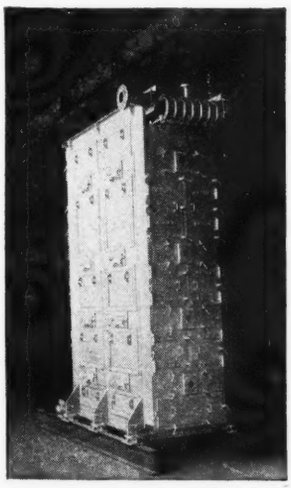
BEACON NEW YORK





Cindertraps

For stoker-fired boilers. Good recovery—low draft loss (0.1" to 0.2"). Tested in accordance with the latest A. S. M. E. Tentative Code, issued December, 1939.



Cast Iron Economizers
(right)

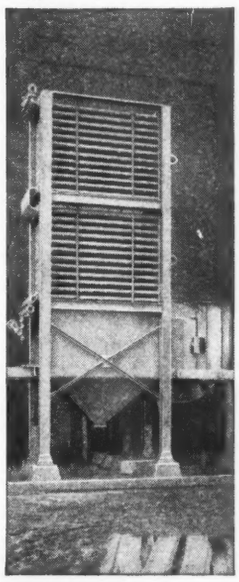
A type still having many advantages as proven by years of service. Built for pressures up to 450 lbs. per sq. in.

Steel Economizers
(left)

High heat-transfer provided by extended-surface construction. A size for every service—pressures up to 1625 lbs. per sq. in.

Air Preheaters
(below)

Tubular and plate types. Waste heat recovery with minimum maintenance. Many in service throughout industry.



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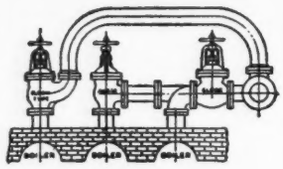
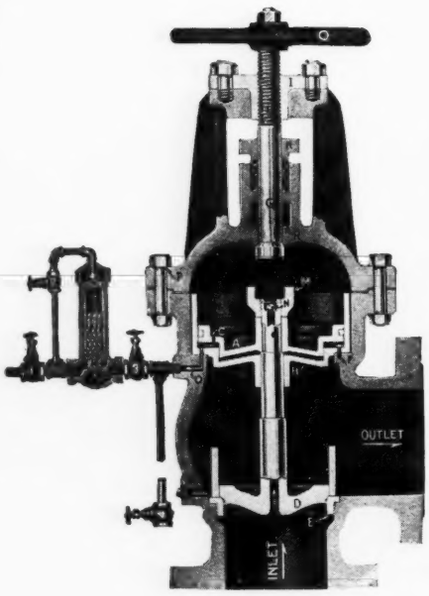
Specialty

VALVES





TRIPLE-ACTING NON-RETURN

• You can make safety in your boiler plant a certainty when you use G-A triple-acting non - return valves. There'll be no boiler explosions or bursting steam lines to damage life and property when you use this double cushioned valve that will not stick or chatter. Comes with either flanged ends or welded necks, and handles 150 lbs., to 1500 lbs. Test it under pressure . . . it's the heaviest valve of this kind made. In angle, globe or elbow types from 2½″ to 16″ in size. Free G-A catalog describing complete line will be sent to you upon request.

also

Altitude Control . . .
Pressure Reducing . . .
Throttle and Emergency Stop . . . Check Valves etc.

Golden-Anderson Valve Specialty Co.

Fulton Bldg. • • • Pittsburgh, Pa.

Pittsburgh, Pa., as representative throughout western Pennsylvania and in neighboring districts of Ohio and West Virginia. Also recently appointed is Manufacturer's Supply Co, Washington, D. C.

ALLEN-SHERMAN-HOFF Co has opened an office in New York, at 271 Madison Ave. B C Berry and P D Oesterle are in charge.

Floating Power Plants Proposed up to 50,000 Kw

Floating power plants which can be towed through America's coastal and inland waterways and hooked up to regular distribution lines to generate electricity in an emergency may be a factor in the National Defense Program, according to A P Kellogg of the General Electric Turbine Division.

Speaking before the Wisconsin Utilities Association at Milwaukee, Nov 12, Mr Kellogg said that a recent study showed a large portion of the eastern United States and the West Coast could be reached by generating stations housed in vessels designed to pass through the New York State Barge Canal.

A projected 50,000-kw self-contained floating power plant is being studied by the General Electric Co, the speaker stated. "This seems to be the largest rating practicable. Of course, floating plants can be built in any ratings under 50,000 kw. The equipment of the floating power plant in general closely follows standard marine and central station practice with modifications necessary to meet low head room," Mr Kellogg said.

The complete 50,000-kw steam-generating station he described could be housed in a hull similar to that of a lake freighter. Dimensions of the vessel were limited to an over-all length of 290 ft, a 43-ft beam, 10-ft draft, and a low bridge clearance of 15 ft.

The idea of floating power plants is not new. The U.S.S. *Lexington*, a turbine-electric-drive battleship, supplied much needed power to the City of Tacoma, Washington, in 1929 when a shortage of water reduced the power supply below the city's requirements.

Two 10,000-kw turbine-generators were installed in the hull of the *Jacona*, a ship built during the last war, and it has been used by the Public Service Co of New Hampshire as a floating power plant since 1930 in New England. At present it is in service on the Piscataqua River near Portsmouth, New Hampshire.

Mr Kellogg pointed out that the yearly station peaks vary on many of the large utility systems, and that if one or more of the floating power plants were available it could be moved from one power house to another as load requirements dictated.

"With the present rapid expansion of industrial loads in locations which are hard to predict, the floating power plant can be placed at an advantageous point on short notice," Kellogg said. "On the larger systems, where it is known that the total load will grow during the next two or three years, but where it is difficult to decide upon the most economical location for a new generating unit, one *power* barge could

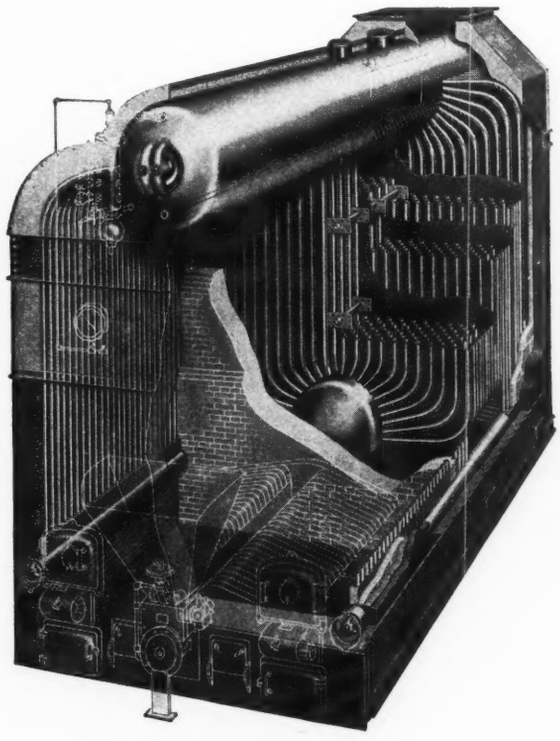
Don't Take Our Word for it—

READ WHAT OWNERS HAVE TO SAY

"I didn't realize how antiquated my old boiler was until I installed a Keeler CP steam generator."

- "Our fuel cost for the two years, 1938 and 1939, was $10,180.00 less than for the two preceding years, 1936 and 1937. Since this boiler has already paid for itself, we feel that our judgment in selecting this equipment has been thoroughly vindicated."
- "I would recommend these boilers to any one in need of high-pressure boilers. We have found them to be everything that the E. Keeler Co. claimed for them."
- "These boilers have lived up to our expectations on efficiency, capacity and quick pick-up. We do not believe we could have made a better purchase."
- "We have used one of the E. Keeler Co. Type CP boilers for the past three or four years and we are more than pleased with same. In fact, I am confident we are saving 15 to 25 per cent over any other boiler we have used."
- "In comparison with a heavy duty boiler we formerly had on the same job, we are saving several hundred dollars monthly; in fact, we find that it will pay for itself in a period much shorter than the engineers figured."
- "We have had two of these generators in service at our plants for the past few years and during this time have experienced nothing but the best performance. They are well constructed and the maintenance on them has been practically nothing."

(Names will be given on request)



TYPE CP

Sizes from 50 h.p. to 1000 h.p.
Pressures to 450 lbs.

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Builders of Better Boilers Since 1864

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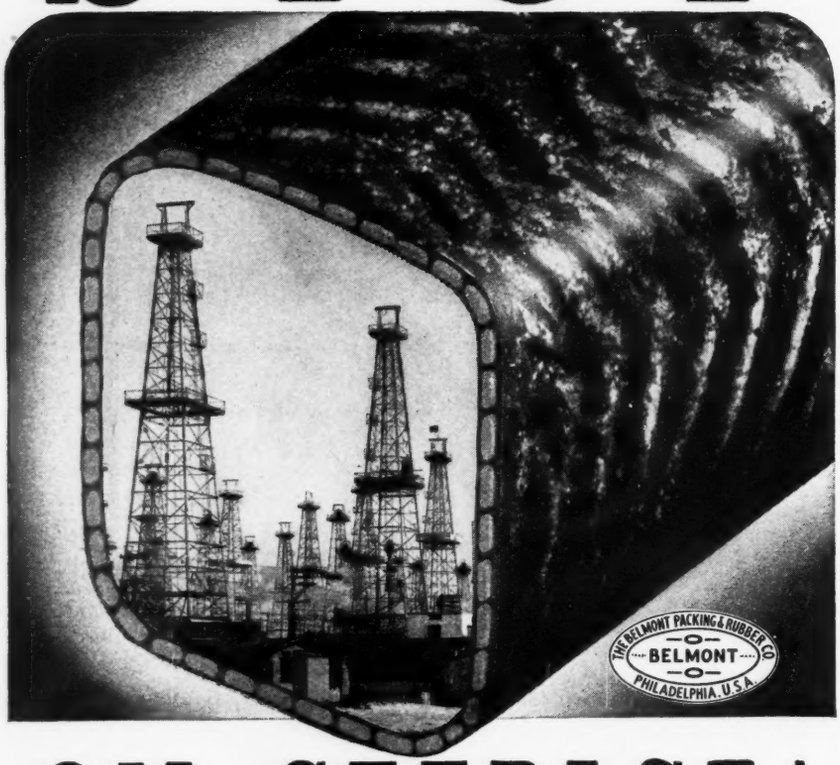

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PACK WITH BELMONT

End that drip drip drip! It's a profit eater —a fire hazard—exposes all your operations to possible loss.

Belmont 6100, illustrated above, is especially designed for use on rods and valve stems handling volatile distillates. Gasoline, naphtha, kerosene and benzol tend to break down ordinary lubricants. But Belmont 6100 uses a *special* lubricant (our exclusive formula) that keeps it soft, retains its sealing qualities longer. The fact that many of the largest refineries use Belmont 6100 is proof that it does the job better.

6100 is just one item in the complete line of Belmont oil packings built to give maximum performance in all types of oil service. Belmont also makes packings for other services. And each Belmont Packing is constructed for ultimate wear and greater efficiency.

The complete line of Belmont Packings (for all types of services) is described in detail in the new FREE 1940 Catalog. Write for it on your company letterhead today!

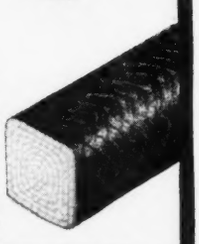
Suggested Belmont Packings For Oil Service

BELMONT 6100

Gasoline Packing Made of high grade asbestos yarn, braided jacket over jacket. Special lubricating compound keeps packing soft and retains sealing qualities even when applied to volatile distillates Square cross section. Available in 1, 3 and 5 lb. spools and in sizes from ⅛" to ⅜"

BELMONT 189

Hot Oil Asbestos Packing. Long fibre asbestos yarn, braided jacket over jacket. Oil penetration and saturation minimized by a special formula lubricant. Designed for use on either hot or cold oil rods and plungers Square cross section. Supplied in packing space sizes from ⅛" up



THERE'S A BELMONT PACKING FOR EVERY SERVICE

BELMONT

PACKINGS

THE BELMONT PACKING & RUBBER COMPANY

BUTLER AND SEPVIVA STREETS • PHILADELPHIA, PA.

be used at any point until a permanent power plant could be made. As an auxiliary to the National Defense Program, the value would be great, as additional power could be made immediately available for replacement or increasing production."

In describing the 50,000-kw floating power plant his company has been studying, Mr Kellogg said that four boilers would be used. These would be similar to the standard oil-burning marine-type boiler, with the addition of an air preheater and a somewhat smaller economizer. The stacks would be made with separable connection so that they could be removed for transportation beneath bridges.

The power plant would have a net output of 50,000 kw. The steam turbine would be direct-connected to the main generator and a house generator which would carry the auxiliary load. It would operate at 3600 rpm and be of the tandem-compound type, double-flow with side exhausts. The steam cycle could be comparable with standard central station practice, with the same steam pressure and temperature and full feedwater heating system.

Power Equipment

The main generator would be rated 50,000-kw, 0.80-power-factor, 62,500-kva, 3-phase, 60-cycles, 13,800-volts. Direct connected to the main generator would be a house generator rated 3500-kw, main and pilot exciters, and a house exciter. The main generator would be hydrogen-cooled with the surface gas coolers within the generator casing. A surface air cooler would provide cooling air for the house generator.

The condensers would be horizontal tube, single pass, similar to the usual central-station design, excepting that the steam connections would be at the side.

Auxiliary equipment would be similar to the usual central station, with feedwater heaters, deaerator, makeup water and storage tank, fuel-oil pumps, boiler-feed pump, and forced draft fans.

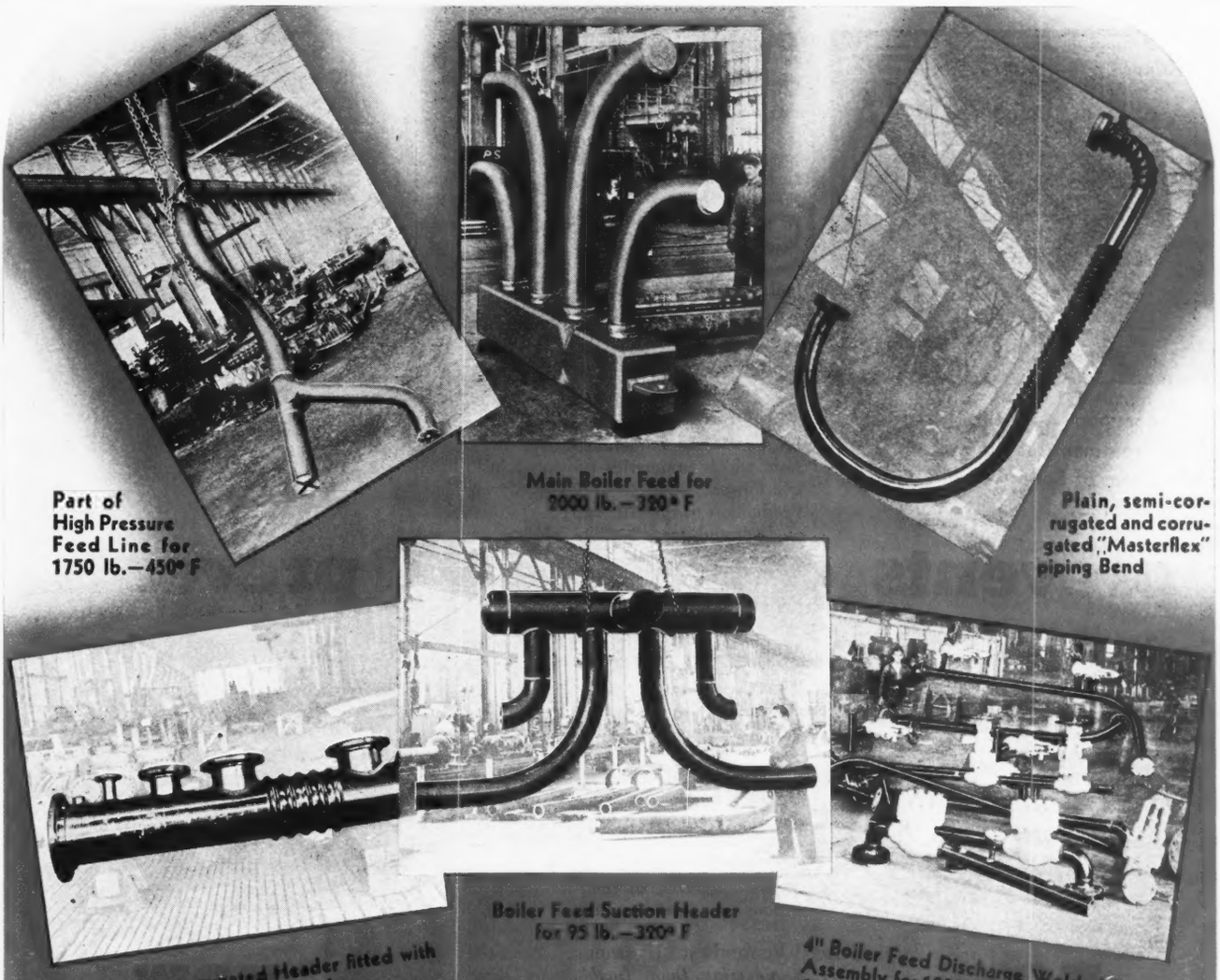
So that the unit could be started from cold, an auxiliary diesel-driven generator of approximately 500-kw capacity would be included. Some lights and a small amount of power would probably be required while the vessel is being towed and a gasoline or diesel-driven generator of about 20 kw would be needed for this purpose.

Fuel oil and fresh water tanks to be carried in the hull would have a capacity for 10 to 15 hours operation, so that the floating power plant could operate immediately on its own until a supply tanker could be brought alongside.

Plans for the hull also call for a double bottom for fuel or water storage or ballast, which would permit lightening the vessel to get over shallow draft points or taking on extra weight to get under low bridges.

Accommodations would be included in the plans for the crew's offices, locker room, washroom, and mess hall.

Mr Kellogg stated that the operation of such a plant would be comparable with that of a good, modern central station. Performance at full load is estimated at 12,000 to 12,500 Btu per kw-hr, figured on the basis of power output from the vessel and including all auxiliary requirements.



Part of High Pressure Feed Line for 1750 lb.—450° F

Main Boiler Feed for 2000 lb.—320° F

Plain, semi-corrugated and corrugated "Masterflex" piping Bend

Partially corrugated Header fitted with outlets and nozzles

Boiler Feed Suction Header for 95 lb.—320° F

4" Boiler Feed Discharge Welded Pipe Assembly for 1000 lb.—250° F—Pipe of Carbon Steel—Valves of Carbon Moly

THESE KELLOGG PREFABRICATED HEADERS ETC. OVERCAME MANY PIPING DIFFICULTIES....

Kellogg prefabricated piping assemblies, headers, bends, tangents, etc. provide the most satisfactory answer to many piping problems.

Consulting engineers, operators of central stations, industrial and marine power plants have found that a satisfactory method of solving their difficult piping problems is to turn the entire responsibility over to the M. W. Kellogg Company.

KELLOGG

THE M. W. KELLOGG COMPANY

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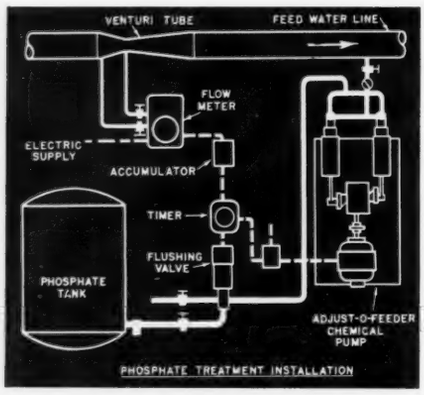
"Masterflex" Prefabricated Piping Systems • **"Masterweld"** pressure vessels for Power, Refinery and Chemical Industries. Heat Exchangers. Pyrolytic Cracking Units. Thermal and Catalytic Polymerization Units • **JUIK Processes** for Lubricating Oil Plants. Plastic Refractories • Radial Brick Chimneys.



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SCALE FORMATION and

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as well as the safety and reliability of the steam generating unit

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offers a complete line of constant rate, time responsive or flow responsive phosphate, sulphate, sulphite, etc. feeding equipment for *all* operating pressures with either steam, air or hydraulic drive—self-contained, flexible, trouble-free.

For further information write for Bulletin TOU-6E or send flow data and rough layout of your boiler water system to

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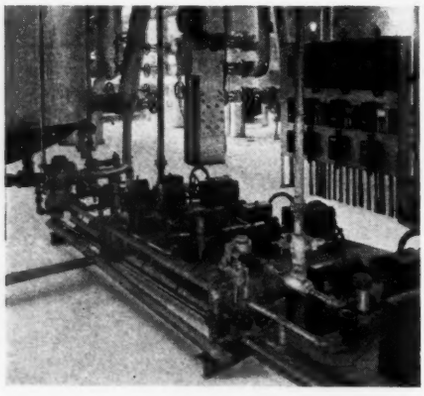


* Licensed under Butzler patent

Engineers' Books

(*Continued from page 130*)

PRESSURE HEATING BOILERS. *Published by Institute of Boiler and Radiator Manufacturers, 60 East 42nd St, New York, N. Y. 78 pages, paper bound, graphs and charts. Price $.30.*—Code shows accurate method for determining performance of heating boilers known as the I-B-R Testing and Rating Code.

SUPPLEMENT TO ELECTRIC POWER STATISTICS (1939). *Published by Federal Power Commission, Washington, D. C. Publication FPC S-7. 135 pages, price $.25.*—Supplement contains detailed data by states from which summaries presented in "Electric Power Statistics—1939" were prepared. Production of electric energy, consumption of fuel and movement of electric energy across state lines are all shown by months for 1939. In addition, capacity of generating plants and production of electric energy are further divided by class of ownership and type of prime mover. Movement of electric energy across state lines is presented in such a manner that amount of energy received in any state from any other state is readily available for each month.

TIME SAVER CHARTS. *Published by Heating Div, Fedders Mfg Co, Buffalo, N. Y. Set of four charts, printed on heavy stock, with celluloid-like finish for protection. Available on request.*—Charts are used for accurate figuring of temperature rises for various operating conditions.

PISTON-RING HANDBOOK. *Prepared by Engineering Dept, Double Seal Ring Co, Fort Worth, Texas. Available on request to engineers and operators.*—Covers various problems encountered in operation of internal-combustion engines, steam engines, compressors and pumps, together with recommendations for piston-ring applications designed to overcome various operating difficulties. Contains engineering data and practical information, including tables and reference data.

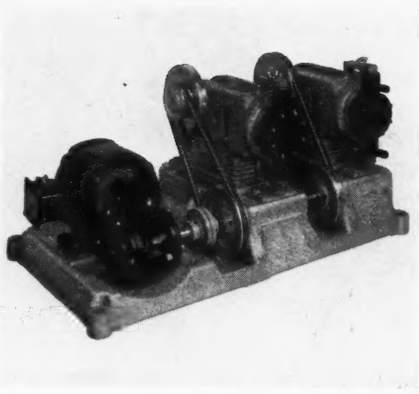
SUGGESTIONS FOR SPECIFICATIONS FOR COORDINATED AND STANDARDIZED LOW-VOLTAGE METERING CURRENT TRANSFORMERS. *Published by Edison Electric Institute, 420 Lexington Ave, New York. 4-pages, price $.10.*—Lists standard suggestions for specifications and shows detailed line drawing illustrating same.

Current Comment

The Power Engineer

Looking back 60 years and more, I note many improvements in matters connected with my profession as engineer; and none of them please me more than the betterment in attitude, experience and ability of those charged with the operation of steam engines.

In the 'eighties, I am reluctantly com-



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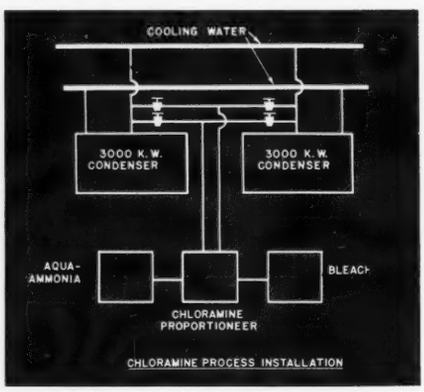

* Licensed under Romans patent

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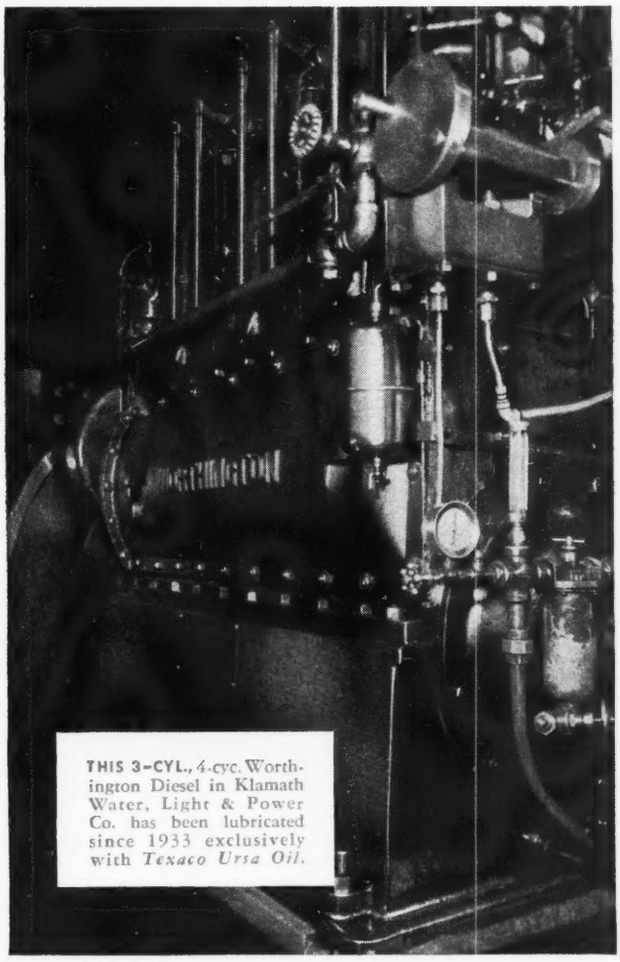

THIS 3-CYL., 4-cyc. Worthington Diesel in Klamath Water, Light & Power Co. has been lubricated since 1933 exclusively with *Texaco Ursa Oil.*

AVERAGING 18 hours a day for 7 years in the Klamath (Calif.) Water, Light & Power Company plant, this 50-kw. Worthington Diesel's performance data show—

1. *Never a stuck ring.*
2. *Original rings still in use.*
3. *Liner wear only .008" at top; not measurable at bottom.*

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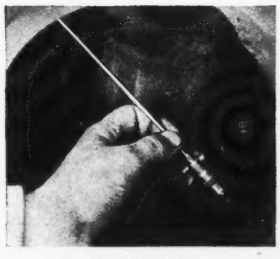
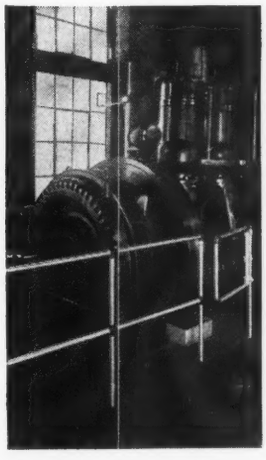
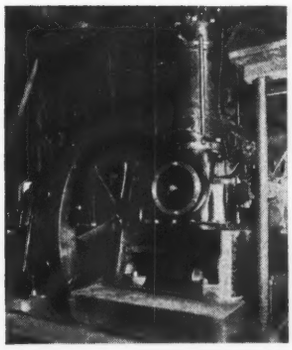


WEAR in the Worthington cylinders was only .008 in. at top after 7 years of 18-hour-a-day operation on *Texaco Ursa Oil.*



NEVER A FAILURE . . . which could be attributed to the oil . . . not even a shut-down, reports Blue Line Hosiery Mills, Inc., Denver, Pa., referring to their 2-cyl. F-M Diesel. They use Texaco Diesel lubricants exclusively.



THIS 1-CYL., 2-cycle F-M unit is also giving an excellent account of itself in the Klamath plant . . . thanks to 7 years on *Texaco Ursa.*

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METROPOLITAN OPERA every Saturday afternoon, NBC. See local newspaper for time and station.

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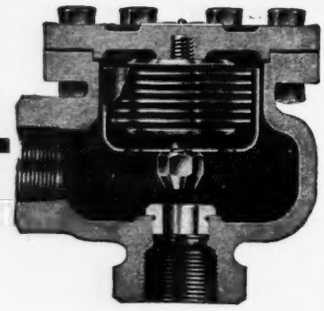

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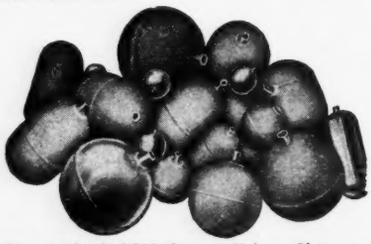

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pelled to say, nine out of ten of those so entrusted were little more than starters and stoppers, and professional engineers objected to their use of the word "engineer" without a qualifying expression, as "stationary," "locomotive," or "marine."

Now, however, attendance at the meetings and conferences of associations of men in this vocation, would convince any one competent to judge, that a new order has arisen. The papers read, the lectures delivered by their own members and by invited professionals, the discussions arising from these papers and lectures, and the contents of their trade periodicals, show that these men intrusted with management and care of valuable property, now as a rule are "engineers" in the strictest sense of the term.

Unfortunately, their employers do not always recognize that fact, very largely on account of their own ignorance of what knowledge, experience, conscientiousness and natural ability it takes to discharge the manifold and increasing duties of engineer efficiently—that is, "to get the most of the best for the least."

The foregoing was intended to lead up to this—that it is the duty of the engineer's employer to supply him liberally with the means to utilize and increase his special knowledge. Above all things, this means providing him with the technical appliances formerly only in the hands of his professional diploma colleagues.

The Modern Engineer

The former mere "engine-runner" or "starter and stopper" has either developed, or given place to, the modern competent power engineer, who, as the expression goes, "knows his engine in his sleep."

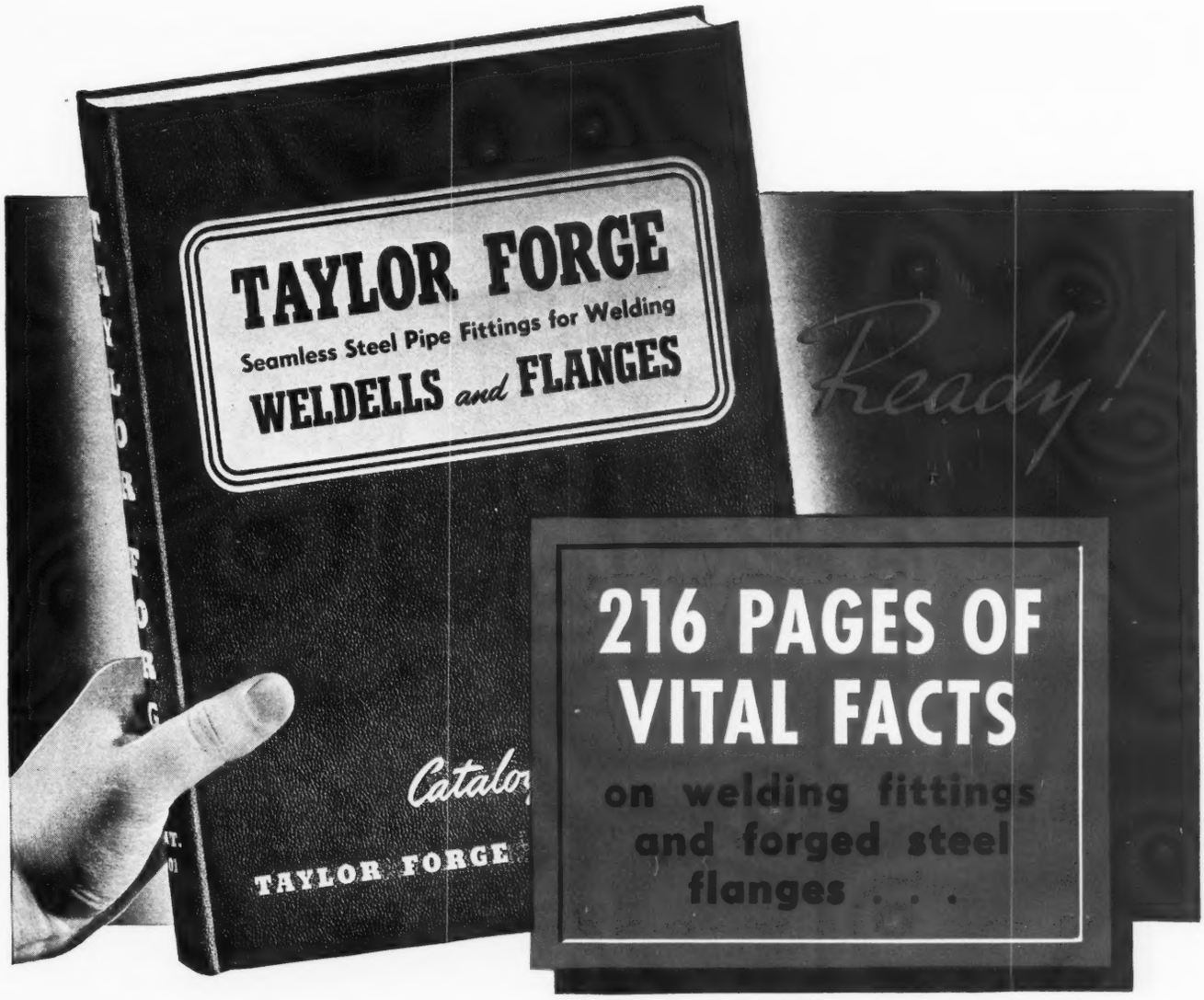
In the 'eighties, the conscientious and ambitious stationary engineer, not satisfied with the working of his charge, took his own free time Sundays and holidays to find out "how and why," by the celebrated Hunt system used by amateur typists.

He attacked the boiler problem; looked for leaks in the setting, breaks in the bridge wall, stoppages in flues; tested the temperature in the uptake; tried various degrees of draft, and satisfied himself as to its regularity; formed an opinion as to the efficiency of grate and of feedwater heater. If he had a test-gage he compared it with the one on duty; he saw to it that there were no sags in steam-pipe leads; and altogether assured himself that the steam supply was dry, prompt and plentiful.

He tried this valve adjustment and that, thought perhaps that the eccentric might be shifted to advantage, and unless it was keyed on immovably, shifted it. In those days, all set-screws were furnished with nice hard sharp points, so as to get a good hold of the shaft; so if on Monday the new adjustment proved unsatisfactory, the next Sunday the eccentric was reshifted either to its former position or to a still newer one, until eventually the shaft had a surface like unto a wood rasp.

At times, yielding to the engineer's arguments and insistence, the owner employed a professional to indicate the engine, point out the cause of the trouble, and remedy it.

But now-a-days the man in charge of a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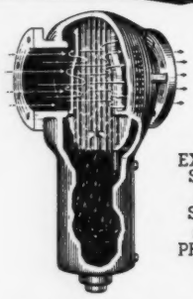

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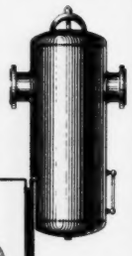
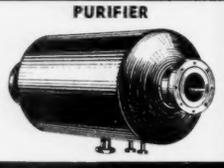


PURIFIER



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high-grade engine knows indicator diagrams; and if provided with the instrument, can apply and use it, and profit at once by the information gained.

This being the case—and provably the case—it is the duty of the engine owner (and to his interest) to furnish the engineer who "knows his onions" with the tools now belonging to his trade; see to it that when he installs an engine it has been already bored and tapped for indication, at the far ends of the clearance spaces, and in such places as will best permit connection with the crosshead. If the instrument (two are better than one) is supplied with a reducing-rig, so much the better; but I guarantee that if it is not, the present-day engineer, if he does not already know how to make the connection, will soon find out, and use the information for the benefit of all concerned.

Leonia, N. J. ROBERT GRIMSHAW

Stops and Starts for Power Engineers

IN THE INTERESTS of adding to the general knowledge of the power engineer, I am sending along the following definitions of words and phrases:

Free wheeling—Attempting to open a gate valve having a sheared stem when the insurance inspector wanted a test on the plant fire pump.

Study in still life—Trap on the alcohol still that wouldn't function because the disk pin of the discharge check valve had failed due to erosion. The disk had broken away and stopped up the discharge line.

Anvil chorus—Sound effects from the operator's automobile after he had filled the crankcase with swiped turbine oil.

Little German band—Acceleration of a certain plant manager who ran into the power plant when an interruption occurred, shouting "Vot iss?, Vot iss?" After being told by the engineer to get the hell out of the way until the situation was back on the line, he had started to leave when the cast-iron flywheel of a motor-driven turbine-governor control came off its shaft and started to bounce down the floor after him.

Rest in pieces—With apologies to the consulting editor. The master maniac's overalls left hanging over the plant storage battery. Add the chief's favorite pair of woolen work pants that had become oil soaked and the bright idea of saving a cleaner's bill by boiling them out in a caustic-soda solution.

Lightning stroke—The crash of broken glass and the momentary flash during a storm last summer. A full row of open windows in the turbine room were smashed and an arc was started across the station auxiliary transformer bus by a chunk of flyash dislodged from the top of the stack during a high wind. It was two days before someone noticed the gap in the accumulated material on top of the stack and lighting was absolved from the blame.—S H COLEMAN.

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A SAFE AND DEPENDABLE COAGULANT FOR BOILER FEED WATER

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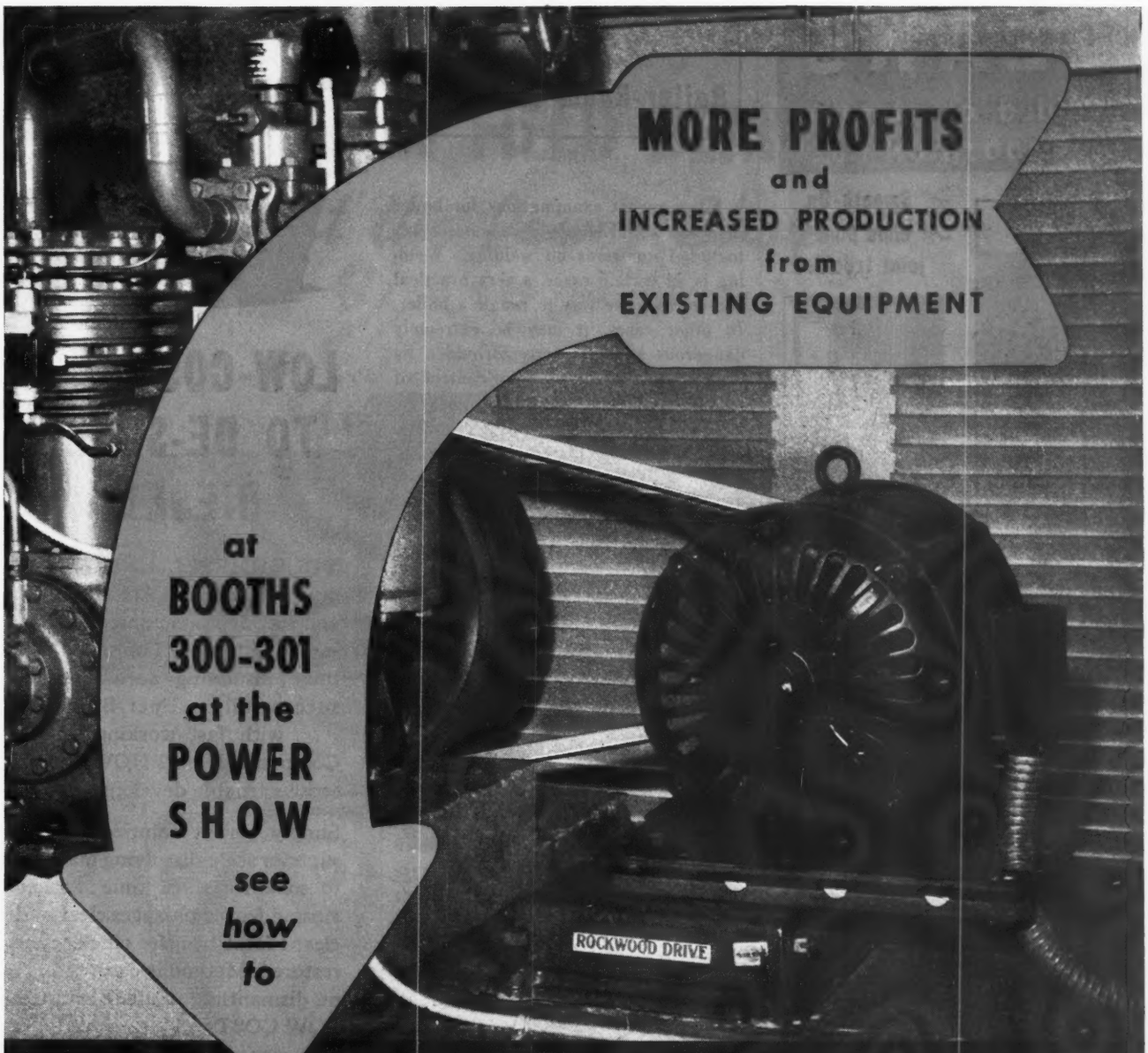

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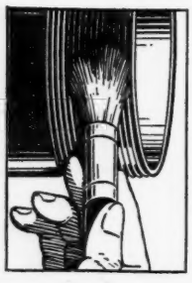

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Questions for Boiler-Room Engineers

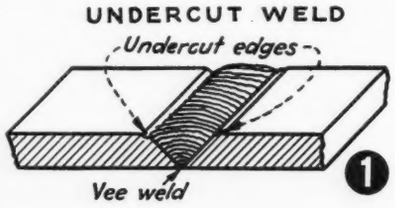
Many recent examinations for boiler inspector's and engineer's licenses have included questions on welding. Welding is, in certain cases, a very practical and inexpensive way to repair a boiler. In other cases, it may be extremely dangerous and is strictly forbidden by Code States. Under rigid control of technique and tests, welding may be used in the construction of new boilers. The ASME Code for Power Boilers describes the required tests thoroughly. The following questions are typical of those asked on the subect:

Q 1—What causes slag inclusions in electric welding?

A 1—(a) Improperly cleaned surface before starting a succeeding pass. (b) Inexpert use of the arc; that is, not floating the slag to the surface of the molten pool of metal. (c) Too low a current, resulting in lack of proper heat to form a pool which will float slag to the surface.

Q 2—How would you tell a poor weld by surface observation?

A 2—(a) Porosity. (b) Irregularities; that is, absence of a regular weave pattern, lumpy, etc. (c) Undercutting;



that is, presence of a valley or groove along the edges of the weld. This may be caused by excess current or voltage burning away the edges of the parent metal, Fig. 1. Another cause of a groove that may not actually be under-

cutting is that a final cover-up pass is not made. This results in an incomplete Vee weld, Fig. 2.

Q 3—What are locked-up stresses?

A 3—When making a weld, the heat causes expansion of surrounding plate. As the weld progresses, the areas of

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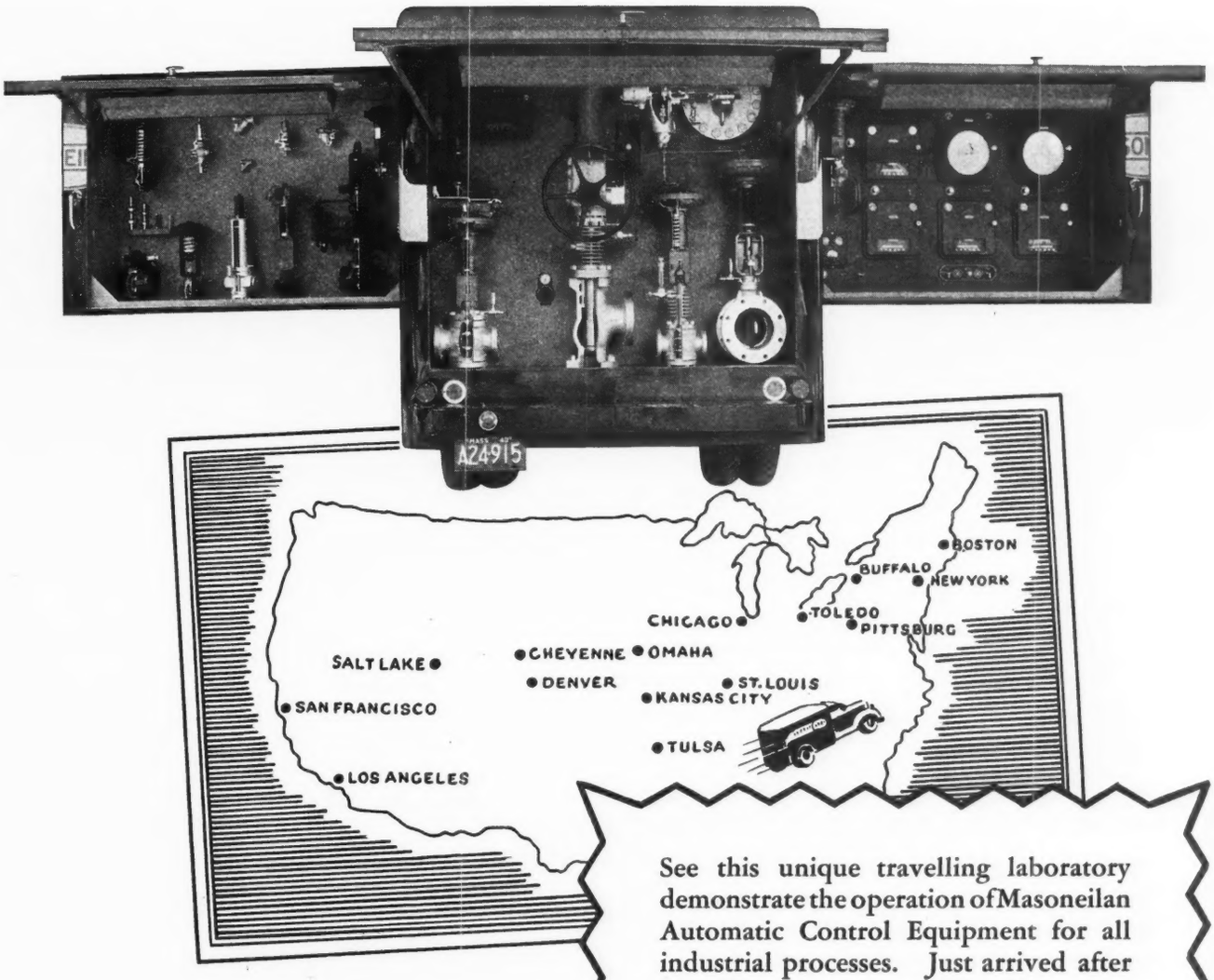

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The CRYER permits water, air and gases to pass from the radiator into the return line while preventing steam from passing and takes the rap and pound out of heating system.

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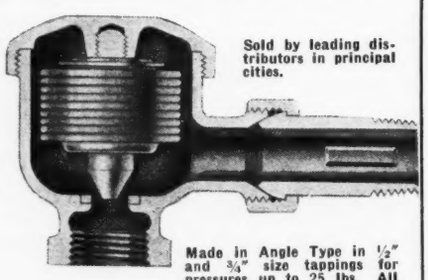

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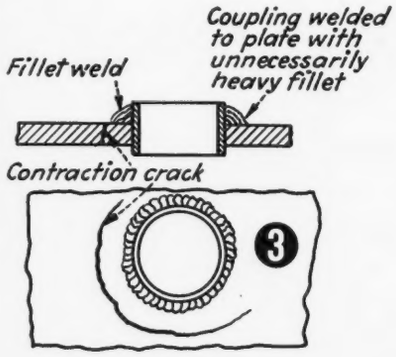
plate remote from the seam cool first. Then as the hot plate adjacent to the weld cools, it tends to contract considerably. As the more remote areas have cooled beyond their plastic state, this contraction tendency sets up locked or residual stresses.

Q 4—What harm may be done by locked-up stresses?

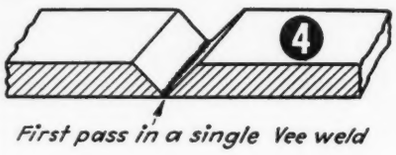
A 4—To the locked-up stresses is added the stress due to operating conditions. The total stresses may exceed



safe limit. Failure may result after the seam has been subjected to operating service, or failure may even result before any additional stresses are imposed, Fig. 3.

Q 5—What may be done about locked-up stresses?

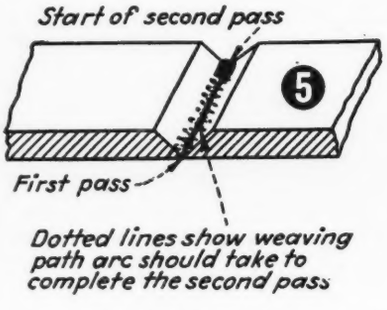
A 5—Stress relieving in accordance with the provisions of the ASME Code



should be followed where the design makes it likely that such stresses will exist.

Q 6—What is a pass in welding? What should be done before starting a succeeding pass?

A 6—(a) A pass is a bead of welding applied along the entire length of the seam. This may be either a string bead (a very small bead applied in the first pass at the root of a Vee), Fig. 4. or a weaving bead as used in succeeding passes, Fig. 5. (b) Before starting



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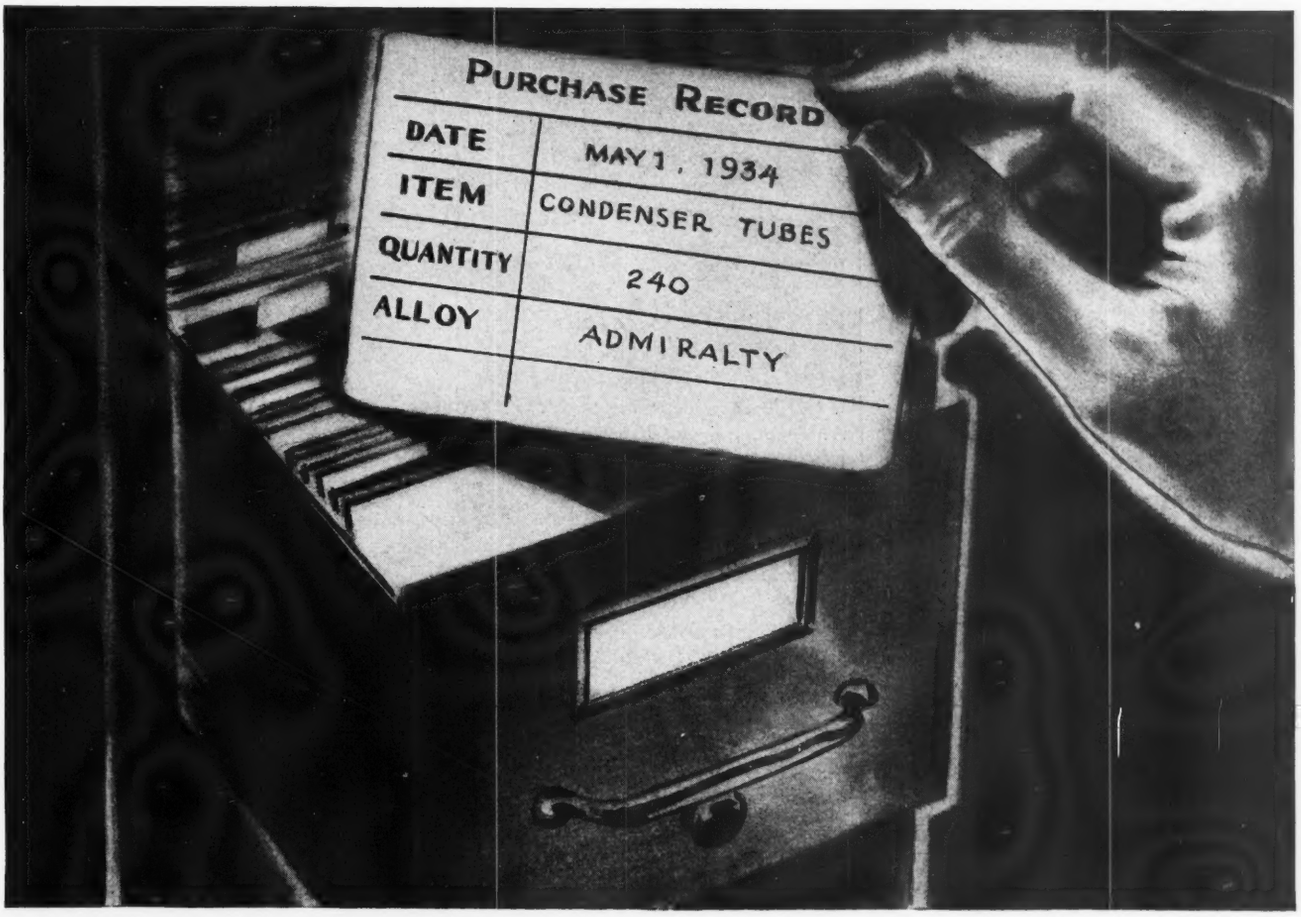

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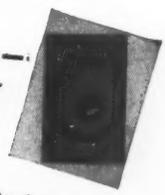

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and you will KNOW what the amount of* EVAPORATION *really is!

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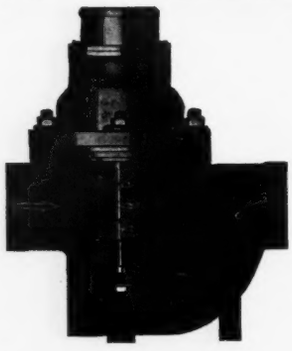


Water enters the measuring chamber tangentially, spinning in the chamber as it passes through, forming a vortex. Each gallon that passes through this chamber makes the same number of revolutions of the water. A vane is placed in the rotating water to impart this rotation to the register. No close clearance—less wear—continued accuracy.

HENSZEY
POWER PLANT SPECIALTIES

a succeeding pass, all scale and slag should be removed. This entails chipping and wire-brushing thoroughly.

Q 7—With what type of welding rod does slag form?

A 7—A coated rod.

Q 8—Is the slag of any advantage? If so, why?

A 8—Yes. It forms an insulating blanket over the weld which protects it from oxidizing effects of the atmosphere while cooling, and also retards cooling. Rapid cooling could, in some cases, result in low ductility.

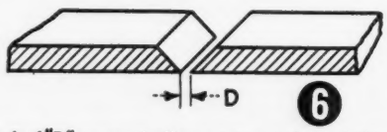
Q 9—Has a coated rod any advantage other than forming a slag coating?

A 9—Yes. The coating forms a blanket of inert gas around the arc to retard oxidation by direct contact between the molten pool and the atmosphere.

Q 10—In the welding of a longitudinal butt seam between two plates, what would be the preparatory steps up to running the first pass?

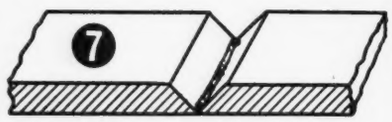
A 10—The edges should be beveled to the proper angle. The edges should be dry, clean, and free from any oil,

Plate in position for tack-welding



Let "D" equal diameter of welding rod for the electric arc process

paint, rust, or other foreign matter. The edges should be clamped or otherwise held in position, separated from each other at the root by about the diameter of the welding rod (Fig. 6). The seam should be tacked then by small welds, about ¼–½ in. in length, at each end and at about each 18



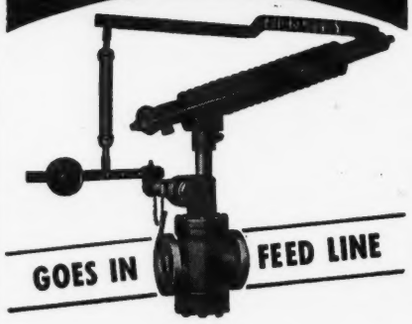
Tack-Welds About every 12" to 18" on long seams, closer on light work

inches along the length of the seam, Fig. 7. If this is not done, expansion and contraction will tend to make the seam close up ahead of the first pass.

Q 11—In welding a seam in boiler plate 1-inch thick, what are the three major requirements of the weld metal?

A 11—(a) A tensile strength of at least that of the minimum of the range of the plate that is being welded. (b) A minimum elongation of 20% in a 2-in. length. (c) A minimum specific gravity of 7.8. That is, a unit volume

HENSZEY
BOILER FEED REGULATORS



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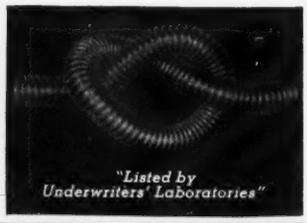

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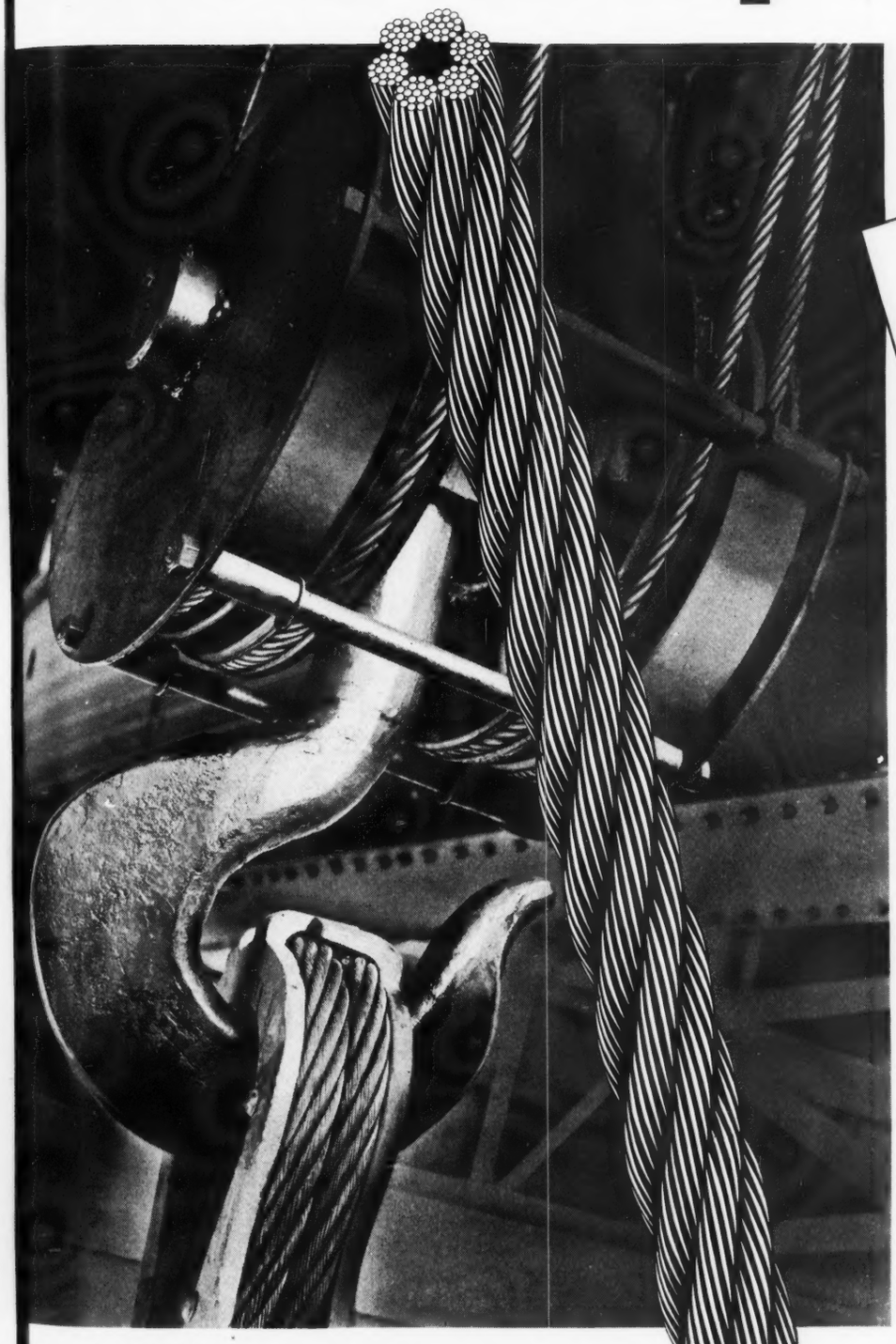

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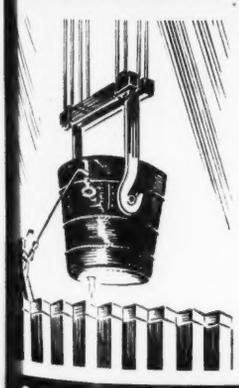

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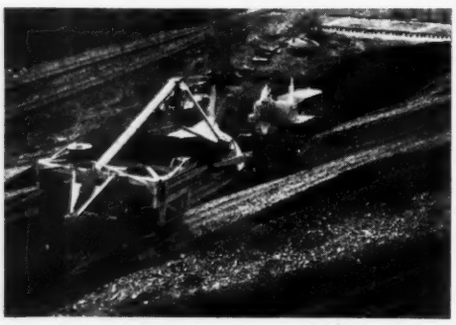

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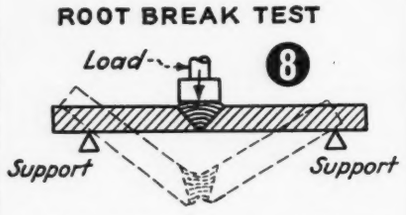
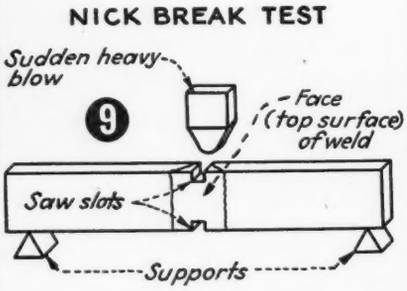
of the welding metal shall be 7.8 x that of the same unit volume of water. As a cubic inch of water weighs 0.036 lb, the minimum weight of a cubic inch of weld metal should be $0.036 \times \frac{7}{8} = 0.28$ pounds.

Q 12—What is the difference between a root-break test and a nick-break test?

A 12—A root-break test is made by taking a strip cut across a welded seam and supporting it at each end with the weld midway between the supports. The base of the Vee of the weld is at the bottom and pressure is gradually applied on the top of the weld. Pressure is increased until failure occurs. while the specimen is bent downward between supports, finally opening up at the root of the weld, Fig. 8.

A nick-break test is made of a similar strip of plate placed between two supports. However, the strip is placed so that the Vee of the weld is in a horizontal plane instead of in a vertical position as in the case of the root-break test. Also, a slot is made on each side of the weld so that failure will be sure to occur at this point. The strip of plate is broken through the seam by





applying a sudden heavy, downward blow at the slotted or nicked point, Fig. 9. Both tests are to determine the soundness, and completeness of fusion of the weld.

Q 13—State a general rule covering the application of welding as a repair to a steam boiler.

A 13—Use welding where it will be for tightness against leakage and not for strength.

Q 14—What is a stitch weld type of plug-weld? Where is it used?

A 14—It is used for tacking the

They Hold

Many types of power plant equipment are subject to vibration or reciprocating motions causing nuts to shake loose on foundations and many other locations as well. These definitely need the protection of

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Fig. 1513

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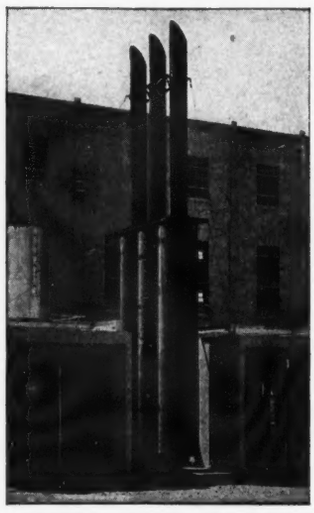

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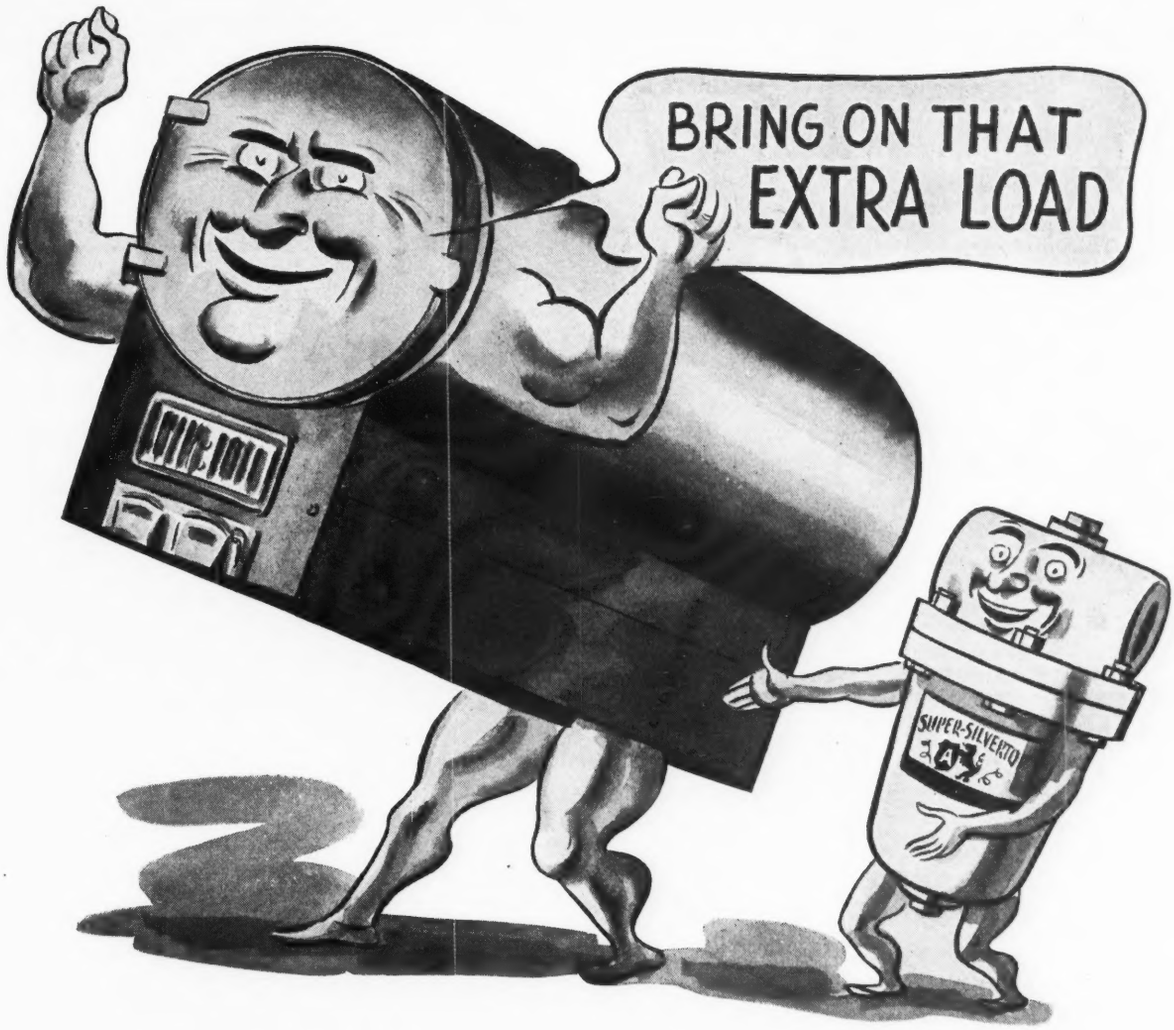

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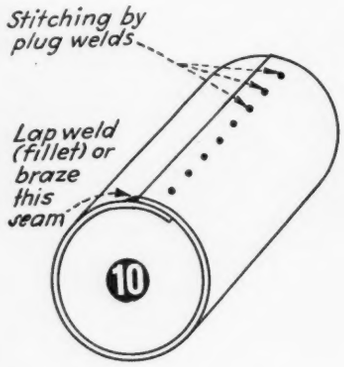
edges of a cylinder in position for brazing or lap welding. A series of holes drilled in the outer lap of the plate are filled with welding so as to fuse through into the inner lap, Fig. 10.



Operating Shorts

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SERVICE TRUCKS for maintenance gangs frequently must transport material which overhangs the rear of the truck, preventing the attachment there of means for the men to get on and off the truck. One company solves the problem by using a detachable ladder with built-on hand rails (see photo). The inner ends of the handrails extend down through holes in the 10-in. pipe forming the end of the truck platform. When it is desired to have unobstructed use of the entire truck floor, the ladder may be removed simply by lifting high enough to disengage it from the pipe.

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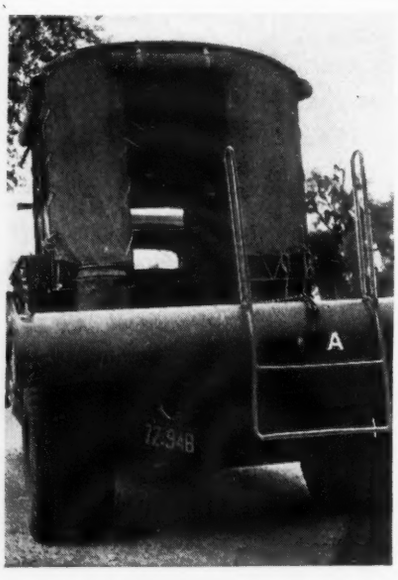

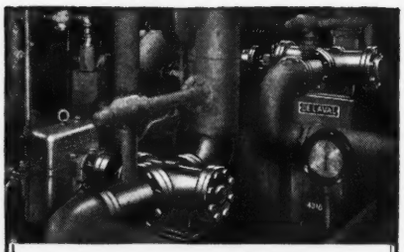

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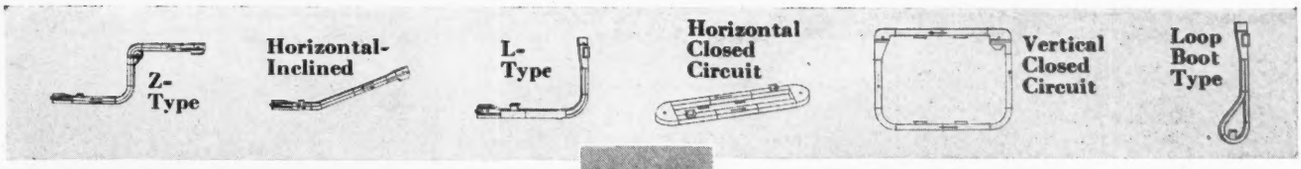

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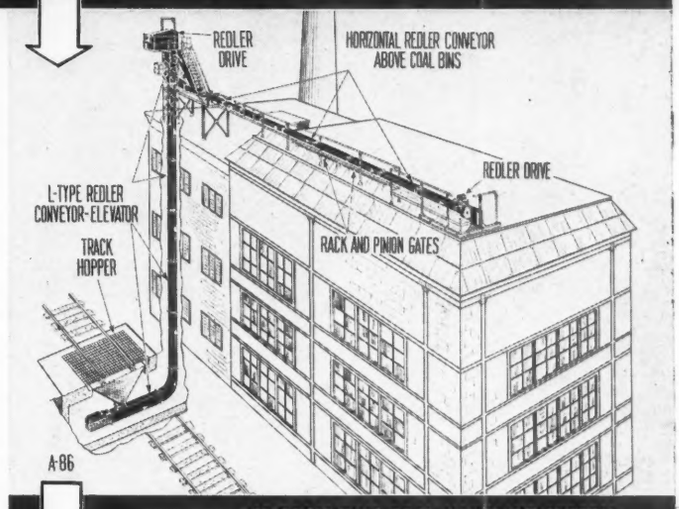
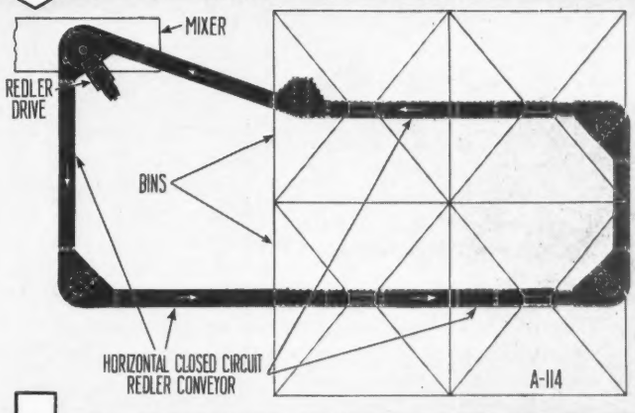


TWO REDLERS FORM THIS COAL HANDLING SYSTEM



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FIND OUT HOW **REDLERS CAN CUT YOUR COAL HANDLING COSTS —**

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ENGINEERS SA MANUFACTURERS

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into which the hook at the end of the winch line may be inserted as at *A*. Now the chain can be hooked in plain view, instead of hooking it to the underpinning of the frame, with danger of hand injury when the driver tightens the hook into place.

Houston, Texas M T PATE

Paint Detects High Temperatures

THE ANSWERS TO THE QUESTION on hot-bearing alarms in October POWER reminds me of a paint I have used for this purpose. First, I thoroughly mix in a mortar 380 grams of 85% copper mercuric iodide with 910 grams of 15% double iodide of silver and mercury with sufficient water to form a paste. When thoroughly mixed, the paste is dried and then ground to a very fine powder. This powder should be washed to remove any soluble impurities as these tend to retard the color change of the paint.

To put the powder in a form for applying to the bearings, mix it with a colorless varnish medium that will stand a fairly high temperature. I use a good white shellac varnish such as used on electrical-machinery insulation. For high temperatures use 100 grams of the powder in 70 cc of shellac varnish.

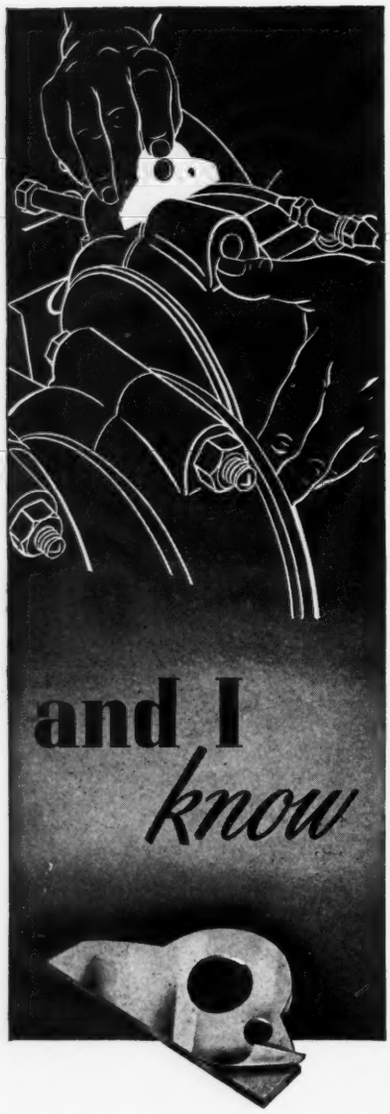
To apply the mixture first paint a white circle on the bearing housing, using a zinc white paint. Then, with the temperature-detector varnish make a bull's-eye on the white background, at the point where the temperature will be the highest. To protect the bull's-eye give it a coat of colorless oil-proof varnish. The bull's-eye has a vivid red color until the temperature reaches about 160 F. when it changes to black. I have found this method of temperature detection reliable and it gives a danger signal well in advance of impending trouble.

Johannesburg, S Africa H DOUGHTY

A Useful Fact

EVERY PRACTICAL ENGINEER carries a few convenient facts and figures in the back of his head, like this one: *One square foot of steel plate, ¼-in. thick weighs 10 lb, Fig. 1.*

This is mighty easy to remember, and very helpful to the engineer making off-hand estimates as he walks around his plant—for example, estimates of the weight of metal in tanks and similar equipment. The engineer takes a quick



and I *know*

it's .002"

The assembly mechanic knows his LAMINUM shims. Each .002 or .003 inch brass lamination he *peels*, leaves a smooth, hard surface; a uniform thickness. Quick precision adjustment—at the job! Machine manufacturers *profit* by LAMINUM cost-cutting of assembly or repair. *Aircraft* too! • *We cut shims to order. Stock shim materials obtainable from mill supply dealers.*

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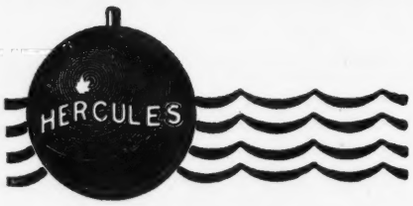

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Every Hercules Float carries our guarantee to stand up under 350 lbs. working pressure and 500 degrees temperature.

Fabricated of seamless copper under our special spinning process. Hercules Floats are uniform in thickness and high in mechanical strength.

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MAKE YOUR
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With Babbitt Sprocket Rims on your overhead valves, you can control valves instantly from the floor. Far quicker and safer than climbing ladders.

Babbitt Rims are easily attached in a few minutes, are inexpensive and assure safe, positive and instantaneous overhead valve operation. Available for valves of every make or style. Write for details.

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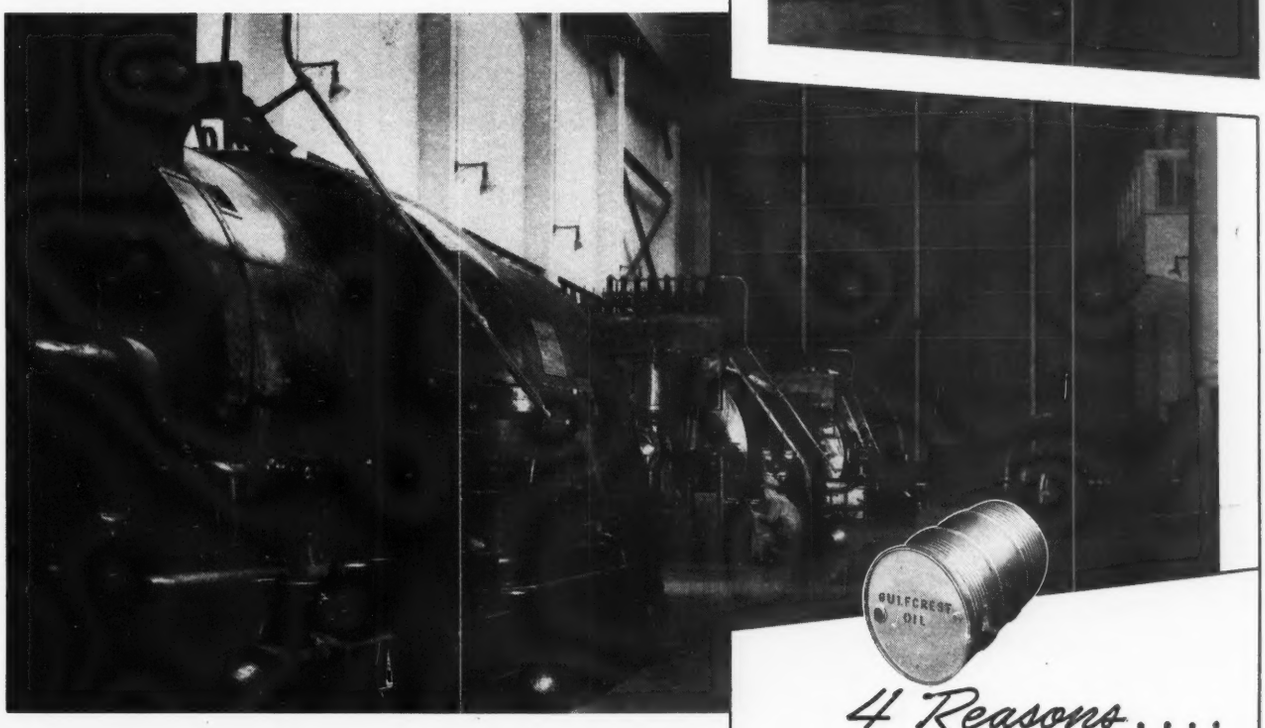
"GULFCREST OIL

is the MOST STABLE TURBINE OIL we've ever used"...

says Power Plant Engineer

GULF PERIODIC CONSULTATION SERVICE plays on important part in the operation of this large modern Power Plant.



"It stays in better condition and lasts longer than ordinary Turbine Oil."

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The performance records of Gulfcrest Oil in turbine systems of many of the leading power plants in the country are unparalleled. Read the four reasons (at the right) *why* Gulfcrest is the finest turbine oil you can buy!

Call in a Gulf engineer and ask him to give you the complete story of Gulfcrest—ask him to explain how GULF PERIODIC CONSULTATION SERVICE will help you maintain greater lubrication efficiency. Write or phone your nearest Gulf office today.

4 Reasons....

1. *Refined by the* ALCHLOR *Process.* The most thorough and effective method for removing chemically active hydrocarbons as well as the general run of impurities present in all crudes.

2. *Highest resistance to oxidation.* This famous ALCHLOR Process synthesizes and rearranges the molecular structure of certain hydrocarbons, resulting in a finished product of greater stability. GULFCREST OIL stands alone in its high resistance to oxidation.

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4. *Highest kilowatt-hour performance.* Because Alchlor not only makes possible an oil more thoroughly refined and homogeneous but also creates anti-oxidants, these oils have great resistance to deteriorating influences and are longer lived. Less make-up oil is required.

This booklet will suggest to you a practical method by which you can reduce operating and maintenance costs for your equipment. Write for your free copy.

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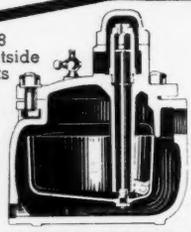
Drainage Equipment for a wide range of Operating Conditions...

Only 8 parts—outside of bolts and pins



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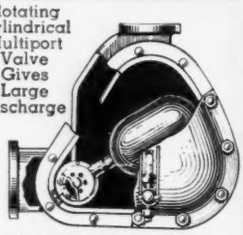
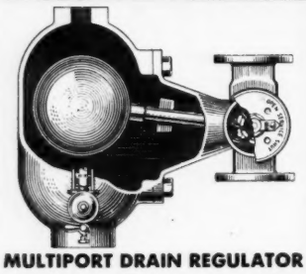
Large cast-iron bucket holds valve tightly to seat until water overflows rim, opening valve wide.

Rotating Cylindrical Multiport Valve Gives Large Discharge



MULTIPORT DRAINER

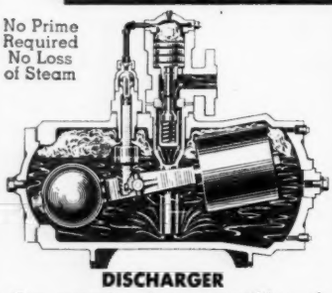
For handling drainage of low-pressure separators or other apparatus where large discharge capacity is required.



MULTIPORT DRAIN REGULATOR

Continuous discharge is maintained by height of condensate in body. Valve shuts off discharge when condensate falls to normal level. Tremendous discharge capacity.

No Prime Required
No Loss of Steam



DISCHARGER

For removing large quantities of condensate under high pressure (150 to 2000 lb./sq. in. or higher) from heaters, purifiers, coils, etc.

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Cochrane Corp., 3106 N. 17th St., Phila., Pa.
Please send me copies of your Publications on Condensate Drainage.

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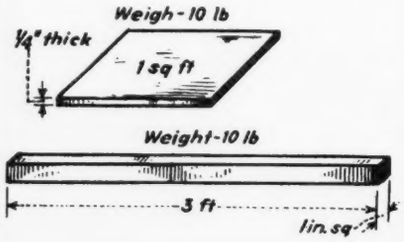
look, say, at a tank 10 ft in diameter and 20 ft long, made of $\frac{3}{8}$-in. plate. Obviously the $\frac{3}{8}$-in. plate will weigh 15 lb per sq ft if the $\frac{1}{4}$-in. plate weighs 10 lb. A 10 ft diameter tank will be about 30 ft around, so the area of the curved surface (about 20 ft long) would run about 600 sq ft. Each end of a 10-ft tank will have about 80 sq ft. Adding these up, we get



about 760 sq ft. At 15 lb per sq ft, this will amount to about 11,000 lb of steel, from which a rough estimate of the cost of materials can quickly be made.

If the $\frac{1}{4}$-in. plate weighs 10 lb, it is obvious that $\frac{1}{8}$-in. weighs 5 lb, $\frac{3}{16}$-in. $7\frac{1}{2}$ lb, $\frac{3}{8}$-in. 15 lb, $\frac{1}{2}$ in. 20 lb, $\frac{5}{8}$-in. 25 lb, and so on. For all commercial grades of steel, these are correct within 2%.

Here's another way to state the rule: *A 1-in. square rod of steel, 1 yard long, weighs 10 lb, Fig. 2.*

New York, N. Y. JOSEPH GISH

Stoker Sales Up

Factory sales of mechanical coal stokers of all sizes and types show an increase of slightly over 50% for the first nine months of this year as compared to the same period in 1939, and $65\frac{1}{2}$% increase in sales over the corresponding months of 1938, according to figures just released by the U. S. Dept of Commerce based on reports supplied to the Government by 107 manufacturers. Sales for this year to date (Oct. 1, 1940) were 109,042 stokers, exceeding by 5000 units the total sales for all of 1939.

Sales in September of this year broke all existing records for sales in any previous month in the history of the stoker industry. Sales reached 31,337 units as compared with 20,600 in the same month of 1939, an increase of 52%.

Sales of Class 1 stokers (less than 60 lb of coal per hr) for residential and small commercial heating purposes in 1940 (January-September, inclusive) totaled 97,657 units, or nearly 90% of total unit sales.

PLUS POWER MINUS COST

"The Entirely Different Boiler and Engine Treatment"

SAND-BANUM Users in many industries know the purchase of Sand-Banum is not expense but investment; "Plus Power—Minus Cost".

It actually costs nothing to use Sand-Banum because of saving in fuel, power and money through elimination and prevention of wasteful scale and corrosion.

TODAY write for trial offer details.

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Specify **BATES**
FOR LONG-TIME ECONOMY

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BATESGRATES
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Each intersection, and consequently, each complete panel of Batesgrates, is strictly one piece. Non-slip, sharp top edge, self cleaning cross bars like the ridge of a roof. No cracks, joints, or acute angles. No grooves to hold grease and dirt and create slippery spots. Batesgrates are an engineered assembly of bars—all bars work.

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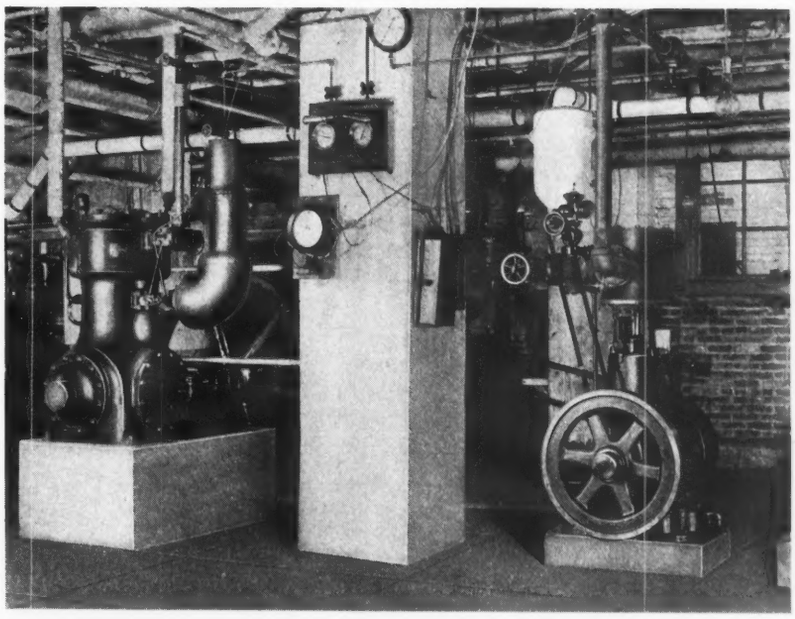
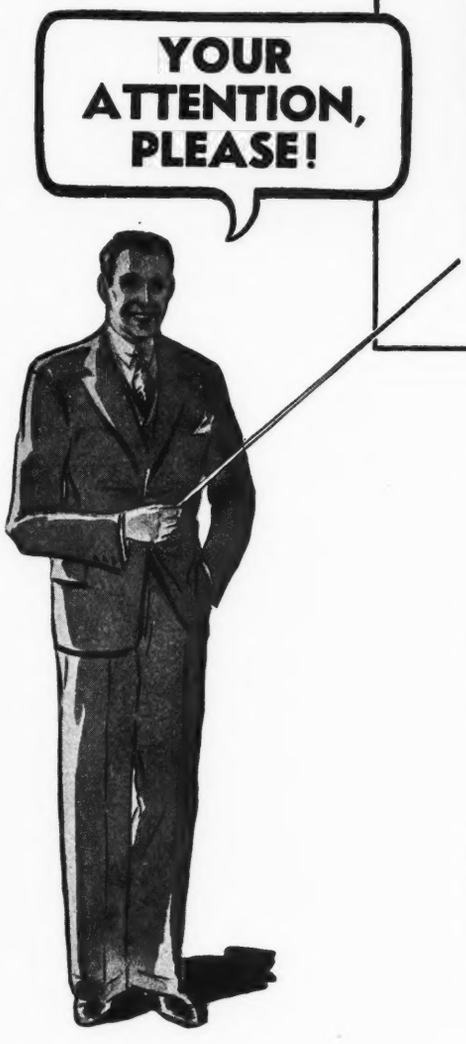




Unit: Troy-Engberg Steam Engine Driving Refrigeration Compressor

Location: Penn-Harris Hotel, Harrisburg, Pa.

Installed Cost (Including all carrying charges) . . $978.00

Annual Savings over Motor $1930.83

That, in a nutshell, is the story of a modern drive saving the user a lot of money each year!

Why not at least *investigate* the merits of this engine as the drive for equipment in your plant . . . as the drive for that stoker, pump, fan, blower, dryer, compressor, generator, cooker?

If conditions are right, you will save considerably over any other type of drive. In addition you will be getting a power unit with excellent drive characteristics and 100% dependability. Speaking of that, here's the way a user in Winnipeg recently expressed it:

> "This unit (a 11"x10" Troy Engine driving a gas pump) was installed about eleven years ago and has run continuously for 24 hours per day except when stopped for short periods for minor adjustments, for repacking piston rod and valve rod stuffing boxes, and for changing oil."

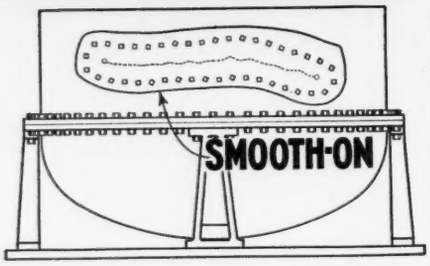
Again we suggest: *investigate* the merits of this modern steam engine for your requirements. Start by sending for descriptive literature.

TROY ENGINE & MACHINE CO.

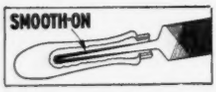
Established 1870

1468 RAILROAD AVE., TROY, PA.

From a cracked machine casting to a loose tool handle



dozens of plant repairs can be made with SMOOTH-ON



The money-saving uses of Smooth-On are almost endless. This many-purpose iron repair cement will seal cracks in casings of boilers, heaters, pumps, valves, piping and machinery parts, will stop leaks at pipe connections, seams, bolts, rivets, screws, etc., and will tighten loose fixtures and parts of equipment all over the plant.

Smooth-On has been doing these jobs successfully for 45 years, as thousands of engineers can testify. It is easy to apply, requires no heat. special tools, nor previous experience, hardens quickly, becomes stronger with age, and makes a lasting repair.

FREE 40-Page Handbook

Every engineer should have a copy of this useful repair manual, with 170 diagrams and simple instructions for ingenious, practical short-cuts in emergency repairs and routine maintenance jobs. Your copy sent free if you mail the coupon.

Buy Smooth-On No. 1 in 1-lb., 5-lb. cans or 25-lb., 100-lb. kegs from your supply house or if necessary, from us. For your protection, insist on Smooth-On—used by engineers since 1895.

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Do it with
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$200,000 Research Program for Bituminous Industry

Bituminous Coal Research, Inc, the research agency of the bituminous coal industry sponsored by the National Coal Association, announced in November the inauguration of a $200,000 program of research aimed to advance the competitive position of coal by the development of better equipment for its use in home and industry. Following the plan adopted in the previous three and one-half year program of the corporation, Howard N Eavenson, president, has completed arrangements with Clyde E Williams, Director, Battelle Memorial Institute, to carry on the program at Battelle.

The broad program of research will include studies of methods by which close control of heating and smokeless operation may be combined with the natural advantage of coal as a low-cost source of energy. The direct application of coal as a fuel for metallurgical and ceramic furnaces, methods for the complete gasification of coal for industrial and residential use, and the direct conversion to mechanical energy through the use of coal in a new type of internal-combustion engine are among the many problems that will be subjected to attack.

That the many thousands of low-cost homes of the country may have cooking and heating stoves that are smokeless and require the minimum of attention, the kitchen ranges and space heaters will occupy a prominent place in the program. In line with the previous program, residential stokers and coals for use on them will be the subject of investigation.

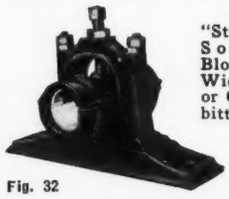
Further research on materials for the dustproofing of coals, with particular attention to those porous coals, now difficult to treat economically, is expected to broaden the distribution of clean-to-handle coal.

Financed jointly by the coal producers' associations, by individual producers, and by the coal-carrying railroads, the program is set up for a minimum period of three years. With approximately 25% of the country's coal tonnage already enlisted, participation in the movement is open to all interested in the advancement of the interests of bituminous coal. E R Kaiser, assistant to the president, who was active in obtaining the support of the producers and the railroads, will continue his efforts to enlarge the scope of the program to a size that will be commensurate with the importance of the bituminous industry.

"STANDCO" PILLOW BLOCKS

Fig. 1635

Combining clamp block and pillow block requirements in one type, the "Standco" shown above is sturdily built and is offered in a wide range of sizes. Babbitted bearing surfaces are finished beautifully smooth, both faces machined. It can be depended on for long, trouble-free service.



"Standco" Ball and Socket Pillow Block, Ring or Wick Oiling, Plain or Collar End Babbitted Bearings.

Fig. 32

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STANDARD PRESSED STEEL CO.
JENKINTOWN, PENNA

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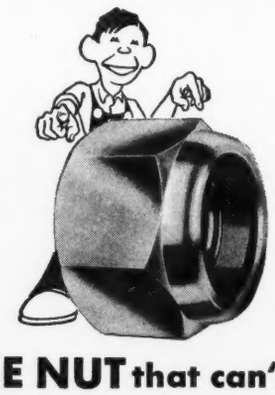
On display at THE POWER SHOW...



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Resilient non-metallic locking collar automatically eliminates thread play and holds thread surfaces in constant pressure-contact.

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2346B VAUXHALL ROAD • UNION, NEW JERSEY

Elastic Stop SELF-LOCKING NUTS

Spray-Spred FIRING METHOD

EXCLUSIVE WITH Fyr-Feeder

IS REVOLUTIONIZING COAL BURNING . .

NOW A TWO UNIT Fyr-Feeder

MODEL R 4072
200 D. H. P. CAPACITY

Only **$995**

F. O. B. FACTORY
CONTROLS EXTRA

OTHER SIZES IN PROPORTION

Sets a new high in Cost Savings

The Multiple FYR-FEEDER Stoker has changed complicated boiler firing to *simplicity itself.* Exclusive, proved, efficient features—few working parts, all slow-moving—most effective, dependable design—new economy that materially cuts former coal burning costs.

Here's how each FYR-FEEDER unit works.—The coal is drawn mechanically from a large hopper to inclines inside the furnace. The coal then rolls down these inclines into air streams under light pressure. Thus, coal is "air-cleaned" and coal dust is "sprayed" and instantly burned in suspension by the air which sprays it. The balance of the coal is spread along the length of the forced draft grate according to weight-size of each piece.

Fire cleaning is easy and takes only a few minutes. FYR-FEEDER Stokers are always built with *two* or *more* individually-controlled FYR-FEEDER Spray-Spred units so that coal feeding on one side of the grate can be stopped, permitting the coal on that side to burn out completely before cleaning or dumping the ashes from that side of the grate. While cleaning fires on one side, *the feeders on the other side are* SPRAY-SPREDing coal to maintain steam pressure.

Spray-Spred capacity of each unit varies according to size and speed and will deliver and Spray-Spred coal up to as much as 500 developed horsepower per unit. Thus, 10 FYR-FEEDER units can be supplied to handle a 5000 horsepower load. Grates may be Stationary, Dumping or Chain Grates (where continuous ash removal is wanted). FYR-FEEDERS may be set directly over fire doors or as much as 10 feet or more above grates.

Learn what the Multiple FYR-FEEDER'S *simplicity and most natural way of firing coal* will do for you. Many hundreds of these FYR-FEEDER Spray-Spred units are proving daily that the best and simplest way to fire any boiler efficiently is to fire coal by SPRAY-SPREDing it over a forced draft fire on a grate.

AMERICAN COAL BURNER COMPANY
155 E. Superior St., Chicago, Ill.
Builders of Over-feed Stokers for Over 22 Years

Fyr-Feeder SIMPLICITY

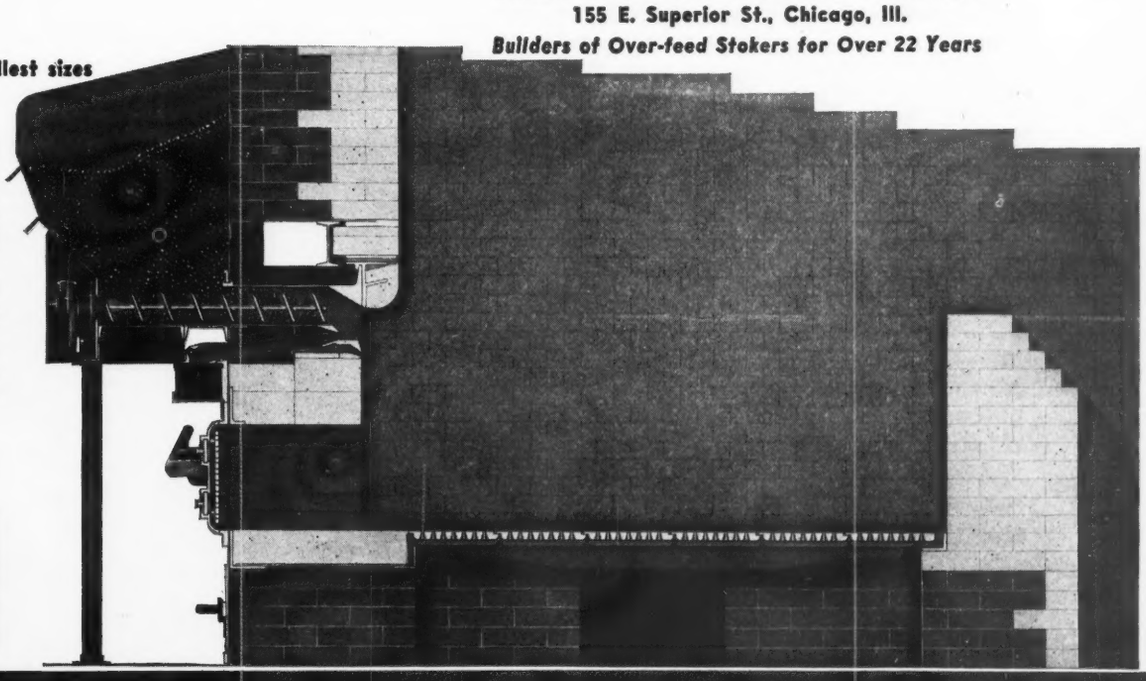
gives you many benefits

- instantaneous ignition of fines
- air spray spreads the coal over grates
- less power to operate
- lower maintenance costs
- reduced steam costs
- burns lowest price coal and smallest sizes
- fires cleaned quicker
- banking losses reduced
- readily adaptable to various types of boilers

AIR-CLEANING all of the coal, inside the furnace, insures a freer air supply to the coal being burned on the grates.

In the FYR-FEEDER furnace, two distinct combustion zones are maintained—one for burning the larger pieces of coal, and one for burning the fines and dust in suspension, each with its own individual, separately-controlled air supply.

Get all the Facts
WRITE TODAY



Spray-Spred MULTIPLE Fyr-Feeder

REDUCES COAL BILLS - - BURNS CHEAPEST COAL SIZES

YARWAY
GUN-PAKT
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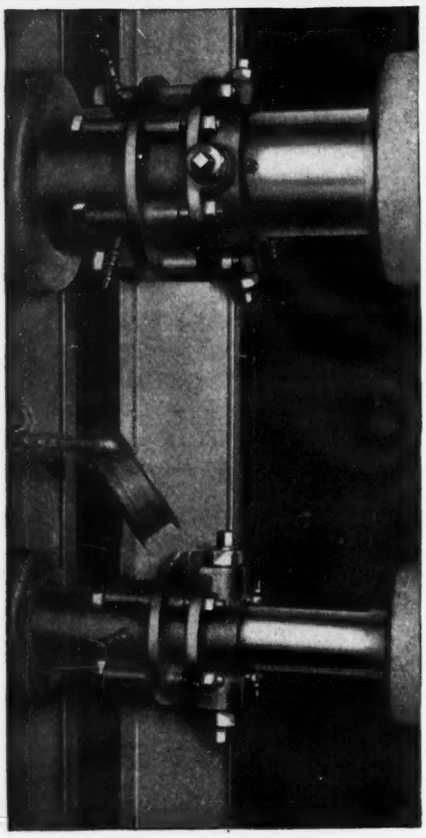
JOINTS



Big Automobile Company Uses 67 Yarway Joints

First purchased 3 years ago. Reordered 7 times to present total of 67 Yarway Gun-Pakt Joints, ranging in size from 3 in. to 14 in.

Why don't you select the Expansion Joint that is packed under full steam pressure. A twist of a wrench forces a special semi-plastic packing into the stuffing box by means of integral pressure guns. No need to remove old packing. New packing rejuvenates the old. No need to shut off steam. Write for Catalog EJ-1907.

YARNALL-WARING CO.
100 Mermaid Ave., Phila., Pa.

A technical committee of fuel engineers representing the companies participating in the program will cooperate with the laboratory in the progress of the work. A smaller advisory group will meet with the research staff at frequent intervals to discuss the latest developments and to steer the program. At Battelle, Ralph A Sherman, supervisor of the fuels division, will direct the work.

As results are obtained, they will be quickly made available to the supporters of the program through reports and bulletins. Bituminous Coal Research, Inc, also plans to be of service to the members by consultation on specific problems, by the dissemination of information in the current literature, and by coordination of research on coal in all parts of the country.

The present program marks the resumption of a previous program of three and one-half years by Bituminous Coal Research, Inc. In that program, the major part of which was likewise carried on at Battelle, research on the problem of the selection and preparation of coal for residential underfeed stokers, on the dustproofing of coal with oil, on the relative economies of house heating with various fuels, on the segregation of coal in industrial power-plant bunkers, on the utilization of coal in pulverized form in steam plants, on the use of coal for the dehydration of hay, and on the possibilities of research in the gasification of coal developed information that has materially aided the bituminous coal and allied industries. With more adequate support from all concerned, the present program is expected to be of even greater service.

C A Reed, engineering director, National Coal Association, is secretary of Bituminous Coal Research, Inc, with offices at 803 Southern Building, Washington, D. C., where M L Garvey, treasurer, and J F Hanley, assistant secretary-treasurer, also have their offices.

In addition to these officers in Washington, and Messrs Eavenson and Kaiser, officers of the corporation include: vice-presidents: R H Sherwood, Central Indiana Coal Company, Indianapolis, Indiana; L W Householder, Rochester and Pittsburgh Coal Company, Indiana, Pennsylvania; and James W. Carter, Carter Coal Company, New York, New York.

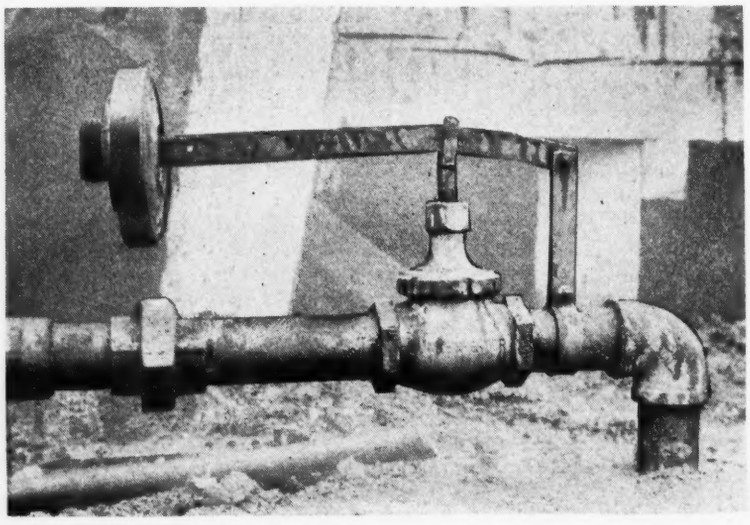
Globe Valve Does Reducing Service

THE PHOTO SHOWS how a temporary primary reducing valve was made from an old globe valve for use on a high-pressure 2-in. gas line. A standard low-pressure reducing valve beyond the one shown made the final reduction and delivered the gas at a constant-pressure to an engine.

Before installing the valve, the threads were turned off its stem so that it would slide easily through the packing. On top of the stem we welded a U-shaped clip for the regulating lever. One end of the lever connects to the pipe and the other carries a weight to close the valve against line pressure, under its seat. Position of the weight on the lever determines the pressure on the down stream side of the valve. Pressure on the packing is adjusted so as not to cause sufficient friction to interfere with the valve's operation.

Needless to say, this type of regulator is not very accurate but did serve in an emergency until something better could be obtained.

Alhambra, Calif. G. M. WILSON



Good Conveyor and Drive Service is Assured with LINK-BELT Silverlink ROLLER CHAIN

One of a number of Link-Belt TWIST-Type Silverlink Roller Chain drives in a western mill. The unique construction of this chain provides freedom for axial twist, yet maintains complete bearing for the pin in the direction in which it is required to carry its normal load. This feature compensates for changes in alignment of the drive.

• Design and mill engineers alike recognize the value of Silverlink's accurately finished, all-steel construction, built to the highest standards of precision . . . that it combines great strength with comparatively light weight . . . that it is extremely flexible, assures smooth operation, and is especially capable of withstanding severe shocks . . . that it minimizes wear and repair. They recognize, too, the value of Link-Belt engineering service in working out problems in connection with the use of roller chains for conveying and power transmitting.

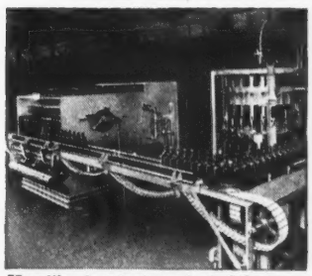
Complete drives—chains and sprockets—from ¼ to 225 H.P., in speed ratios 1:1 up to 8:1 are stocked by distributors throughout the country. Send for Stock List No. P-1557.

LINK-BELT COMPANY

The Leading Manufacturer of Positive Power Transmitting Equipment

INDIANAPOLIS CHICAGO PHILADELPHIA ATLANTA DALLAS SAN FRANCISCO TORONTO

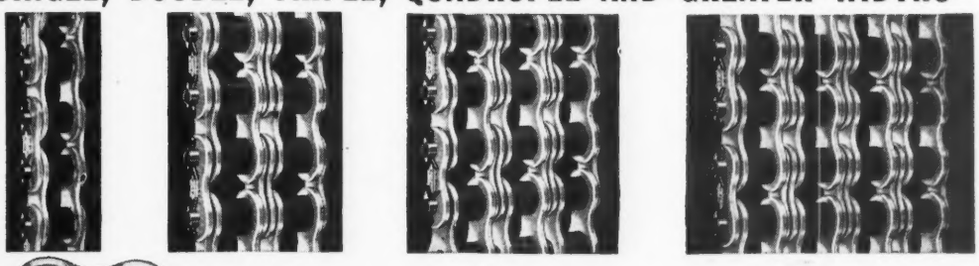
Branch offices, warehouses and distributors in principal cities. 6273C



Handling bottles is typical of the many ways in which Silverlink roller chains with various attachments, speed the handling of small units, cans, jars, glassware, boxes, etc.

Uniform, accurate movement of this series of rolls for handling roofing material were requirements here—Link-Belt Silverlink Roller Chain being the ideal solution for efficient performance and low maintenance.

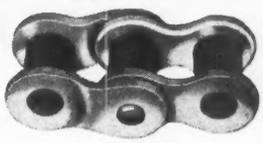
SINGLE, DOUBLE, TRIPLE, QUADRUPLE AND GREATER WIDTHS—



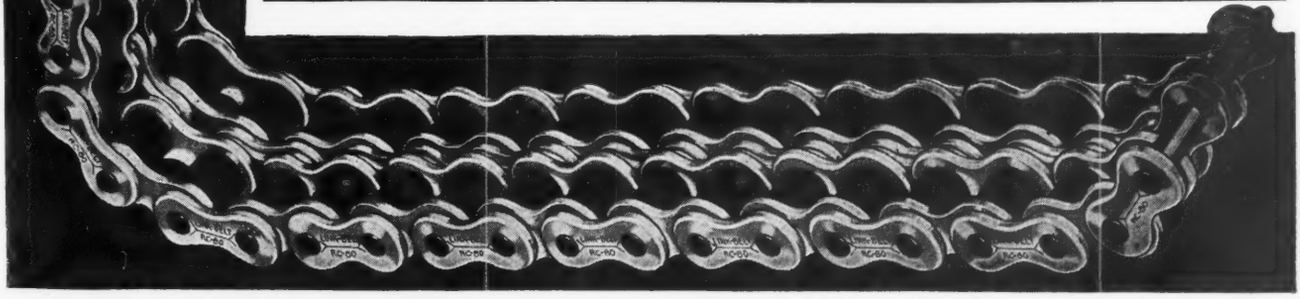
Connecting (Tight-Fit) Link and Coupler (Slip-Fit) Link.

CONNECTING AND COUPLER LINKS

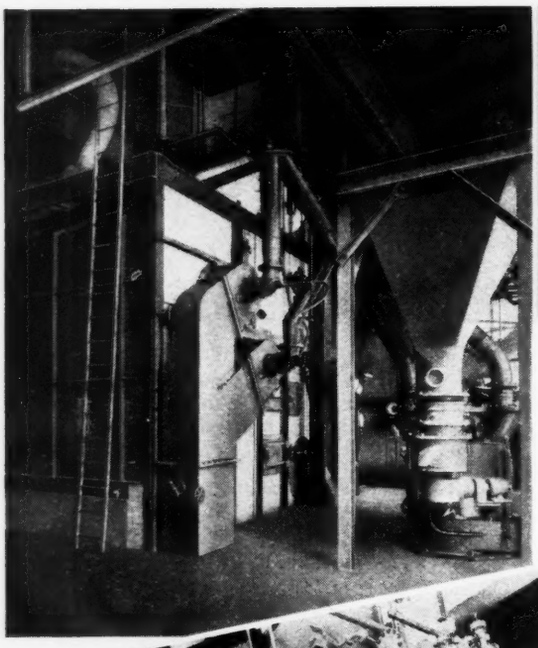
Connecting and coupler links, 1 and 2-pitch offset links, and roller links can be furnished to fit all types of single and multiple width roller chains. Available in detachable cotter pin, spring clip, or riveted type, depending upon the size of chain and service requirements.

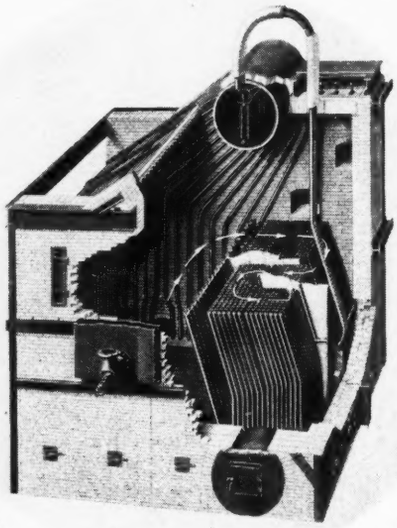


2-Pitch Offset Link

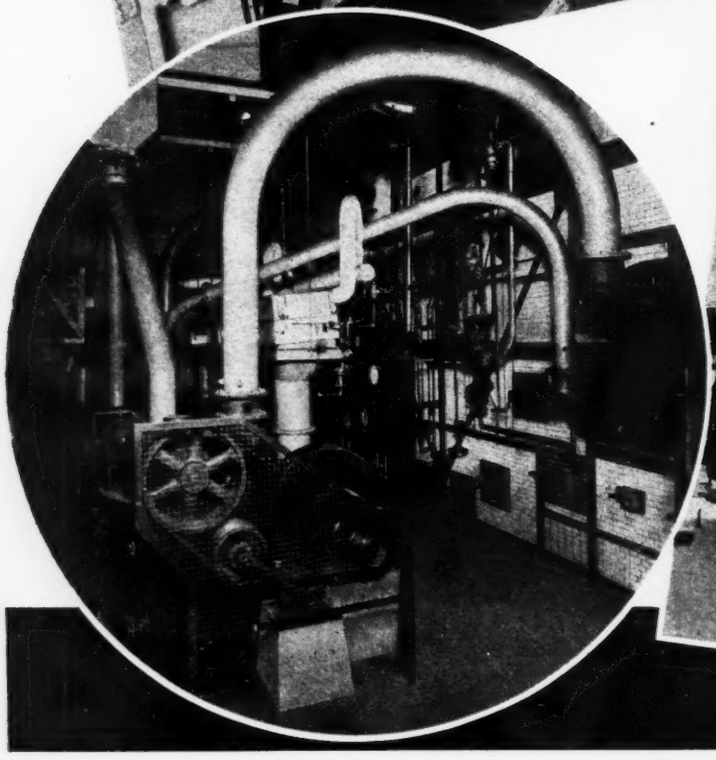


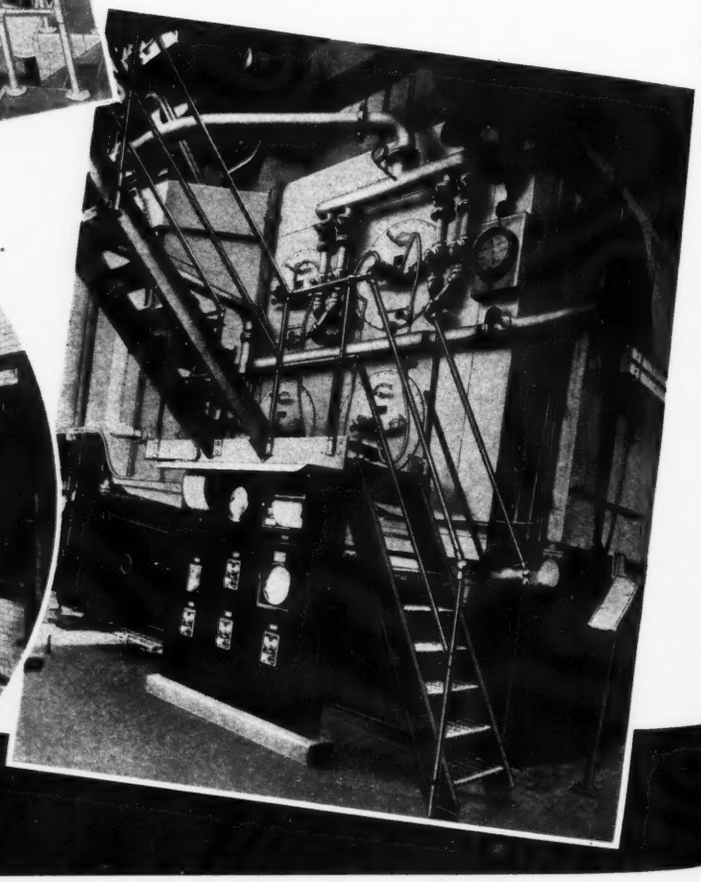
Bought on Faith





Path of gases through slag screen, across large tubes and superheater in first pass, and smaller tubes in the second and third passes.





h Reordered on Performance

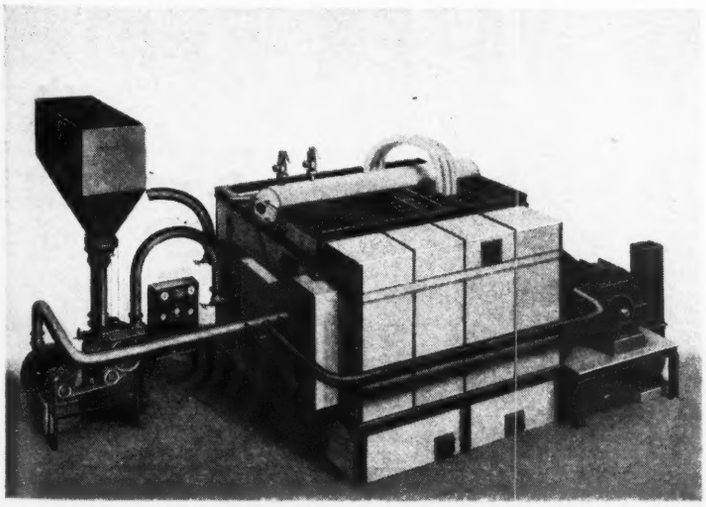
Thirty-two industrial companies and subsidiaries who bought B&W Integral-Furnace Boilers have ordered additional units of the same type. The reorders exceed the total of the original purchases by 54 per cent.

The initial orders were placed on faith in B&W engineering and ability and willingness to make every unit perform as expected. Each repeat order was founded on the owner's experience with the Integral-Furnace Boiler itself, a unit that has demonstrated its ability to meet the ultimate test—satisfactory performance.

Owners of these modern B&W Boilers (more than 275 are in service) know that, all costs included, the B&W Integral-Furnace Boiler produces the most steam per dollar.

For detailed description of B&W Integral-Furnace Boilers, ask for Bulletin G-17-A.

THE BABCOCK & WILCOX COMPANY
85 Liberty Street **New York, N. Y.**



B&W Integral-Furnace Boiler, a modern, complete unit adaptable to small plants as well as to those of moderate size.

CO.	YEAR AND NUMBER OF UNITS ORDERED							
	'33	'34	'35	'36	'37	'38	'39	'40
A							2	3
B				2			3	
C		1		1				
D	2			1				
E		2					1	
F			2		1			
G				4		2	2	
H			1			2		
I				2			2	
J				5	2		3	
K				1	1			
L					1		1	
M					1	1		
N			2			1		
O			1	1	1		1	
P			1				1	
Q				2	1			
R				1		1		
S			1			1		
T	3	1	2		1	2	2	2
U				1			1	1
V				2				1
W						2	3	
X			1		2			
Y				3	4	1	1	
Z			1	1				
AA	3		1			1		1
BB				2				2
CC						2	12	
DD						2	2	
EE						2	1	
FF						2	1	

G-192-T

BABCOCK & WILCOX

GENERATORS · TURBINE-GENERATORS
MOTOR-GENERATORS · MOTORS ·
STEAM ENGINES

ELLI

MECHANICAL DRIVE TURBINES
STRAINERS · FEED-WATER HEATERS
SEPARATORS · DEAERATING HEATERS
DESUPERHEATERS · STEAM JET EJECTORS
NON-RETURN VALVES · TURBO-CHARGERS
GREASE EXTRACTORS · CENTRIFUGAL BLOWERS
LAGONDA-LIBERTY TUBE CLEANERS

RS ENGINE-GENERATORS

ELLIOTT

. . symbol of profitable power

To be truly profitable to its users, power equipment must combine both *reliability* and *economy*. Which is not always easy.

For a piece of equipment can be *reliable* without being *economical*. It can be *economical* (while it runs) without being *reliable*. Combining both factors is a test of character.

This is a test which Elliott equipment must—and does—pass. In order that its manufacture be profitable for us, its operation must be profitable for you. Thus our individual interests are identical, and insure complete satisfaction whether they affect a large turbine-generator and condenser unit, or a ½-inch tube cleaner.

Complete data on all Elliott equipment, in separate bulletins, is available at request. Engineering cooperation offered in all specific problems.

CONDENSERS
DEAERATORS

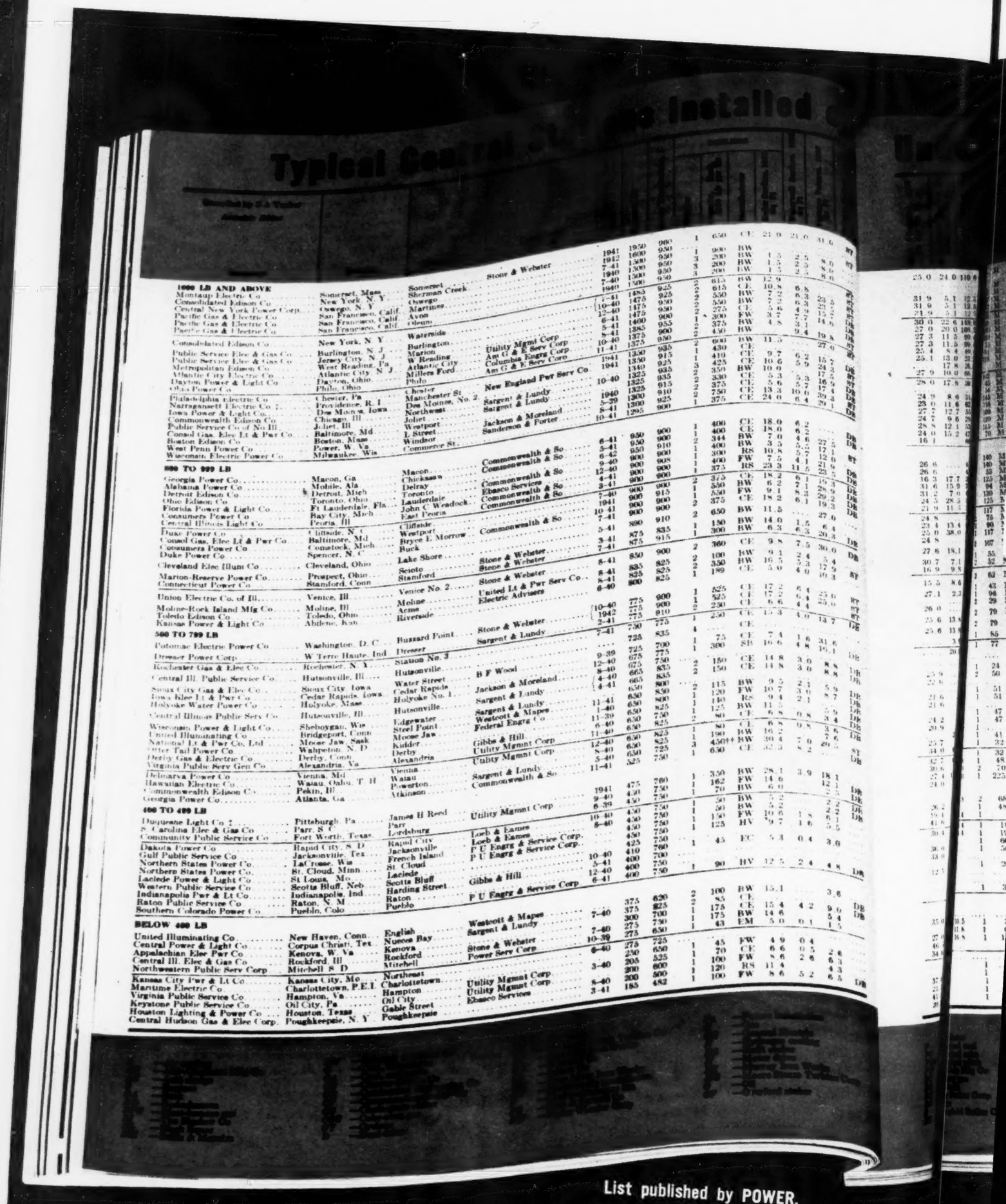
ELLIOTT COMPANY

WORKS:

JEANNETTE PA. — **RIDGWAY PA.** — **SPRINGFIELD OHIO**

DISTRICT OFFICES IN PRINCIPAL CITIES

Q-1074



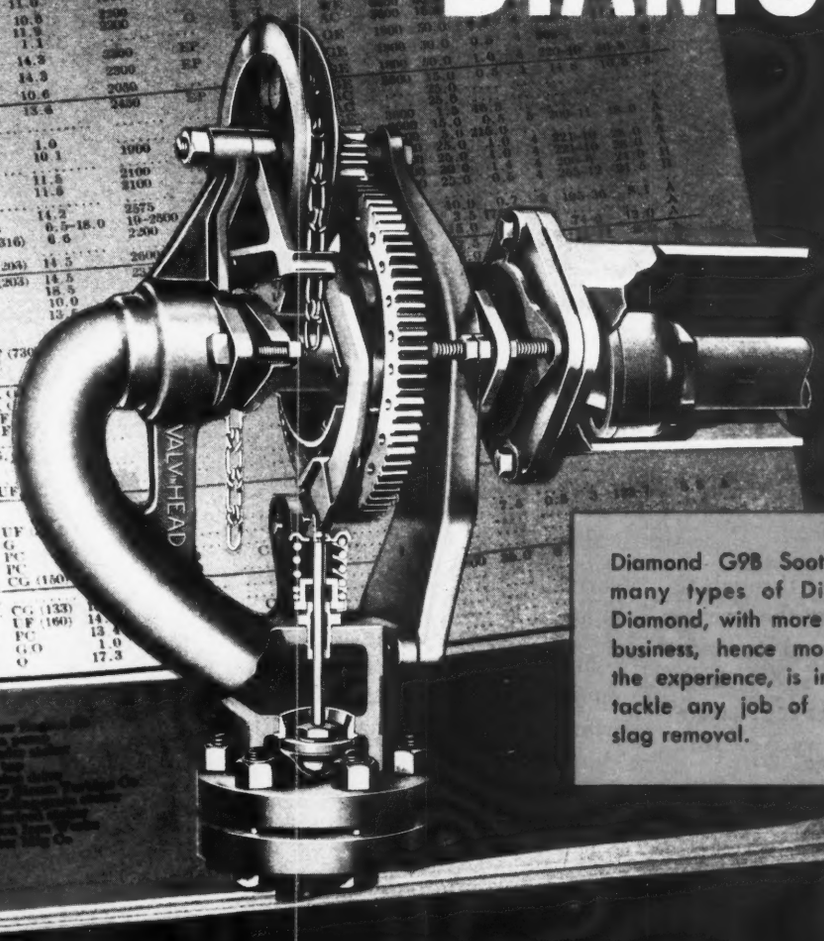
Typical Co... Installed ...

1000 LB AND ABOVE														
Montauk Electric Co	Somerset, Mass	Somerset	Stone & Webster	1941	1950	900	1	650	CE	21.0	21.0	31.0		ST
Consolidated Edison Co	New York, N Y	Sherman Creek		1941	1600	950	1	900	BW					
Central New York Power Corp	Oswego, N Y	Oswego		1942	1600	950	3	800	BW	1.5	2.5	8.0		ST
Pacific Gas & Electric Co	San Francisco, Calif	Martinez		7-41	1300	950	3	800	BW	1.5	2.5	8.0		
Pacific Gas & Electric Co	San Francisco, Calif	Avon		1940	1300	950	3	800	BW	1.5	2.5	8.0		
Pacific Gas & Electric Co	San Francisco, Calif	Oleum		7-40	1300	950								
				1940	1300	950								
Consolidated Edison Co	New York, N Y	Waterside		7-41	1485	925	2	615	BW	12.9				
				6-41	1475	925	2	615	CE	10.8	6.8			
Public Service Elec & Gas Co	Burlington, N J	Burlington		10-40	1475	950	2	550	BW	7.2	6.3			
Public Service Elec & Gas Co	Jersey City, N J	Marion	Utility Mgmt Corp	12-40	1475	950	2	550	BW	7.2	6.3	23.5		
Metropolitan Edison Co	West Reading, Pa	W Reading	Am G & E Serv Corp	6-41	1400	900	2	275	CE	5.6	4.9	23.5		
Atlantic City Electric Co	Atlantic City, N J	Atlantic City	Columbia Engrg Corp	5-41	1385	900	1	300	FW	3.7	7.7	15.7		
Dayton Power & Light Co	Dayton, Ohio	Philo	Am G & E Serv Corp	10-40	1375	950	2	375	BW	4.8	3.1	14.0		
Ohio Power Co	Philo, Ohio	Chester		1941	1350	915	2	450	BW		9.4	19.8		
Philadelphia Electric Co	Chester, Pa	Manchester St	New England Pwr Serv Co	1941	1350	915	1	900	BW	11.5				
Narragansett Electric Co	Providence, R I	Des Moines, No. 2		10-40	1325	935	1	430	CE			27.0		
Iowa Power & Light Co	Des Moines, Iowa	Northwest	Sargent & Lundy	1941	1350	925	1	410	CE	9.7	6.2	15.7		
Commonwealth Edison Co	Chicago, Ill	Joliet	Sargent & Lundy	1941	1340	925	3	425	CE	10.6	5.9	24.3		
Public Service Co of No Ill	Joliet, Ill	Westport				935	3	350	BW	10.0		24.3		
Consol Gas, Elec Lt & Pwr Co	Baltimore, Md	L Street	Jackson & Moreland		1325	935	2	330	CE	5.3	5.3	17.5		
Boston Edison Co	Boston, Mass	Windsor	Sanderson & Porter	10-40	1325	915	2	375	CE	5.6	5.7	16.9		
West Penn Power Co	Power, W Va	Commerce St			1325	910	2	750	CE	13.3	10.0	37.4		
Wisconsin Electric Power Co	Milwaukee, Wis			1940	1300	925	1	375	CE	24.0	6.4	29.1		
				5-39	1300	900								
				8-41	1295	900								
				10-41										
800 TO 999 LB														
Georgia Power Co	Macon, Ga	Macon		6-41	950	900	1	400	CE	18.0	6.2			
Alabama Power Co	Mobile, Ala	Chickasaw	Commonwealth & So	5-41	950	900	1	400	CE	18.0	6.2			
Detroit Edison Co	Detroit, Mich	Delray	Commonwealth & So	6-42	950	910	1	400	BW	7.0	4.6	27.5		DB
Ohio Edison Co	Toronto, Ohio	Toronto	Ebasco Services	9-40	900	900	1	300	BW	3.3	5.5	17.5		DB
Florida Power & Light Co	Ft Lauderdale, Fla	Lauderdale	Commonwealth & So	12-40	900	900	1	300	RS	10.8	5.7	12.1		
Consumers Power Co	Bay City, Mich	John C Weadock	Commonwealth & So	4-41	900	900	1	400	FW	7.5	4.1	21.9		ST
Central Illinois Light Co	Peoria, Ill	East Peoria		7-40	900	900	1	375	RS	23.3	11.5	25.5		
Duke Power Co	Cliffside, N C	Cliffside		3-41	900	900	2	375	CE	18.2	6.1	16.3		DB
Consol Gas, Elec Lt & Pwr Co	Baltimore, Md	Westport	Commonwealth & So	7-40	900	900	2	350	BW	6.2	7.1	16.3		DB
Consumers Power Co	Comstock, Mich	Bryce E Morrow	Ebasco Services	3-41	900	900	1	550	BW	6.2	7.1	28.9		DB
Duke Power Co	Spencer, N C	Buck	Commonwealth & So	7-40	900	915	1	550	FW	9.1	8.3	28.9		DB
			Commonwealth & So	1941	900	900	2	375	CE	18.2	6.1	20.2		DB
Cleveland Elec Illum Co	Cleveland, Ohio	Lake Shore		10-41	900	900	2	650	BW	11.5		19.3		DB
Marion-Reserve Power Co	Prospect, Ohio	Scioto	Stone & Webster	7-41	880	910	1	180	BW	14.0	1.5	27.0		
Connecticut Power Co	Stamford, Conn	Stamford	Stone & Webster	5-41	875	835	1	300	BW	6.3	6.3	6.4		
				3-41	875	915						20.3		DB
Union Electric Co. of Ill	Venice, Ill	Venice No. 2	Stone & Webster	7-41			2	360	CE	9.8	7.5	30.0		
			Stone & Webster	8-41	850	900	2	100	BW	9.1	2.4	5.4		
Molme-Rock Island Mfg Co	Molme, Ill	Molme		8-41	835	825	2	350	BW	16.5	5.3	17.9		ST
Toledo Edison Co	Toledo, Ohio	Acme	United Lt & Pwr Serv Co	8-41	825	825	1	189	CE	5.0	4.0	10.3		
Kansas Power & Light Co	Abilene, Kan	Riverside	Electric Advisers	8-41	800									
				6-40			1	525	CE	17.2	6.4	23.0		
				10-40	775	900	1	525	CE	17.2	6.4	23.0		ST
				1942	775	900	2	250	CE	6.6	4.4	22.0		ST
			Stone & Webster	2-41	775	910			CE					ST
			Sargent & Lundy	7-41	750	775	1	250	CE	15.3	4.0	13.7		DB
500 TO 799 LB							4		CE					
Potomac Electric Power Co	Washington, D C	Buzzard Point			725	835								
Dresser Power Corp	W Terre Haute, Ind	Dresser					1	75	CE	7.4	1.6	31.6		
				9-39	725	700	1	300	SH	16.6	4.8	16.1		
Rochester Gas & Elec Co	Rochester, N Y	Station No. 3		12-40	675	775								DB
				8-40	675	750	2	150	CE	14.8	3.0	8.8		
Central Ill. Public Service Co	Hutsonville, Ill	Hutsonville	B F Wood	4-40	665	835	2	150	CE	14.8	3.0	8.8		DB
				6-41	665	835								DB
Sioux City Gas & Elec Co	Sioux City, Iowa	Water Street			650	800	1	115	BW	9.5	2.1	5.9		
Iowa Elec Lt & Pwr Co	Cedar Rapids, Iowa	Cedar Rapids	Jackson & Moreland		650	850	2	120	FW	10.7	3.0	8.7		DB
Holyoke Water Power Co	Holyoke, Mass	Holyoke No. 1	Sargent & Lundy	11-41	650	800	1	140	RS	9.4	2.1			DB
			Sargent & Lundy	1-40	650	825	1	125	BW	11.5		5.9		DB
Central Illinois Public Serv Co	Hutsonville, Ill	Hutsonville	Westcott & Mapes	11-39	650	750	1	80	CE	6.8	0.8	3.4		DB
			Federal Engrg Co	6-40	650	825								DB
Wisconsin Power & Light Co	Sheboygan, Wis	Edgewater		11-40	650	825	1	80	CL	6.8	0.8	3.6		DB
United Illuminating Co	Bridgeport, Conn	Steel Point	Gibbs & Hill	12-40	650	825	1	190	BW	16.2		7.6		DB
National Lt & Pwr Co, Ltd	Moose Jaw, Sask	Moose Jaw	Utility Mgmnt Corp	8-40	650	725	3	4501++	BW	30.4	7.0	20.5		
Otter Tail Power Co	Wahpeton, N D	Kidder		5-40	650	750	1	630	CE	32.3	8.2			ST
Derby Gas & Electric Co	Derby, Conn	Derby	Utility Mgmnt Corp	11-41	625	750								DB
Virginia Public Serv Gen Co	Alexandria, Va	Alexandria												
Delmarva Power Co	Vienna, Md	Vienna	Sargent & Lundy				1	350	BW	28.1	3.9	18.1		
Hawaiian Electric Co	Waiau, Oahu, T H	Waiau	Commonwealth & So		475	760	1	162	FW	14.6		12.1		
Commonwealth Edison Co	Pekin, Ill	Powerton		1941	475	750	1	70	BW	6.0		2.1		DB
Georgia Power Co	Atlanta, Ga	Atkinson		9-40	450	750						2.2		DB
400 TO 499 LB				6-39	450	750	1	50	BW	5.2		2.2		DB
Duquesne Light Co	Pittsburgh, Pa	James H Reed	Utility Mgmnt Corp	10-40	450	750	1	50	BW	5.2		2.2		DB
S Carolina Elec & Gas Co	Parr, S C	Parr	Loeb & Eames	8-40	450	750	1	150	FW	10.6	1.8	6.1		DB
Community Public Service Co	Fort Worth, Texas	Lordsburg	Loeb & Eames		450	750	1	125	HV	9.7	1.6	5.5		
Dakota Power Co	Rapid City, S D	Rapid City	P U Engrg & Service Corp		450	750								
Gulf Public Service Co	Jacksonville, Tex	Jacksonville	P U Engrg & Service Corp		425	750	1	45	FC	5.3	0.4	3.0		
Northern States Power Co	LaCrosse, Wis	French Island			410	700								
Northern States Power Co	St. Cloud, Minn	St Cloud		10-40	400	700								
Laclede Power & Light Co	St Louis, Mo	Laclede		5-41	400	750	1	90	HV	12.5	2.4	4.8		DB
Western Public Service Co	Scotts Bluff, Neb	Scotts Bluff	Gibbs & Hill	12-40	400	750								
Indianapolis Pwr & Lt Co	Indianapolis, Ind	Harding Street		6-41	400									
Raton Public Service Co	Raton, N M	Raton	P U Engrg & Service Corp				2	100	BW	15.1		3.6		
Southern Colorado Power Co	Pueblo, Colo	Pueblo			375	620	2	85	CE					
BELOW 400 LB					375	825	2	175	CE	15.4	4.2	9.0		DB
United Illuminating Co	New Haven, Conn	English	Westcott & Mapes	7-40	375	700	1	175	BW	14.6		5.4		DB
Central Power & Light Co	Corpus Christi, Tex	Nueces Bay	Sargent & Lundy		300	750	1	43	EM	5.0	0.1	1.5		
Appalachian Elec Pwr Co	Kenova, W Va	Kenova		7-40	275	650								
Central Ill. Elec & Gas Co	Rockford, Ill	Rockford	Stone & Webster	10-39	275	725								
Northwestern Public Serv Corp	Mitchell, S D	Mitchell	Power Serv Corp	6-40	275	650	1	45	FW	4.9	0.4			
					250	650	1	70	CE	6.6	0.5	2.6		
Kansas City Pwr & Lt Co	Kansas City, Mo	Northeast		3-40	205	525	1	100	FW	8.6	2.6	6.3		
Maritime Electric Co	Charlottetown, P.E.I.	Charlottetown	Utility Mgmnt Corp		200	600	1	120	RS	11.4		4.3		
Virginia Public Service Co	Hampton, Va	Hampton	Utility Mgmnt Corp	8-40	200	500	1	100	FW	8.6	5.2	6.5		DB
Keystone Public Service Co	Oil City, Pa	Oil City	Ebasco Services	3-41	185	482								
Houston Lighting & Power Co	Houston, Texas	Gable Street												
Central Hudson Gas & Elec Corp	Poughkeepsie, N Y	Poughkeepsie												

List published by POWER, September, 1940.

81%

OF THE SOOT BLOWERS PURCHASED FOR THESE PLANTS ARE DIAMOND

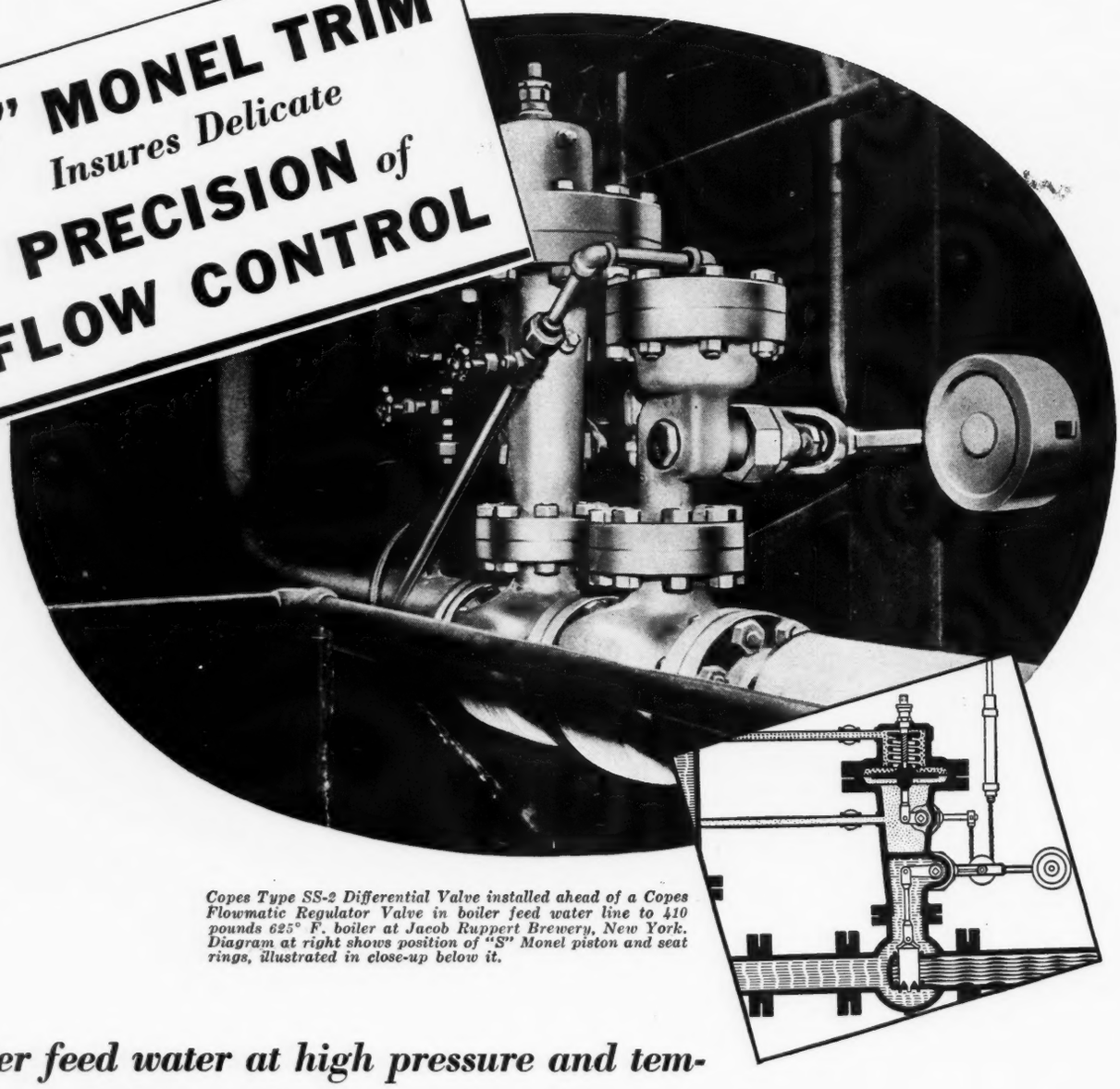


Diamond G98 Soot Blower—one of many types of Diamond Blowers. Diamond, with more than 80% of the business, hence more than 80% of the experience, is in best position to tackle any job of soot cleaning, or slag removal.

DIAMOND POWER SPECIALTY CORP., *Detroit, Mich.*

DIAMOND SPECIALTY LIMITED, *Windsor, Ontario*

"S" MONEL TRIM Insures Delicate PRECISION of FLOW CONTROL



Copes Type SS-2 Differential Valve installed ahead of a Copes Flowmatic Regulator Valve in boiler feed water line to 410 pounds 625° F. boiler at Jacob Ruppert Brewery, New York. Diagram at right shows position of "S" Monel piston and seat rings, illustrated in close-up below it.

Boiler feed water at high pressure and temperature fails to make this regulator "loosen up"

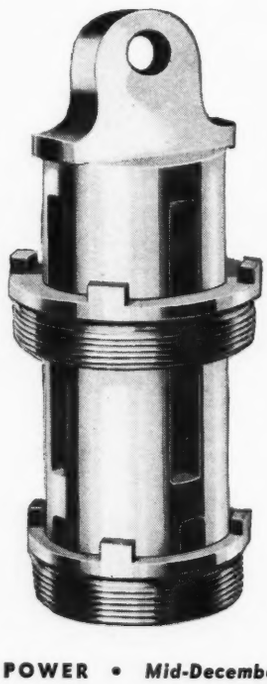
HOT FEED WATER surging through restricted orifices is hard on the average metal. Severe erosive and corrosive action soon cause wear and leakage. But *not* in this feed water regulator at the Jacob Ruppert Brewery, New York, N. Y. Here's why:

In all Copes regulators, made by Northern Equipment Co., Erie, Pa., "S" Monel is standard for pistons and rings. That means a pressure-tight fit *maintained* over long periods of time. For "S" Monel offers stout resistance to corrosion *plus* extreme hardness and non-galling properties.

Many makers of power plant equipment now use "S" Monel for valve trim and other such parts. Readily machined to a smooth finish, "S" Monel resists erosion, corrosion and wear, retains its strength and hardness at high temperatures, and is also non-galling.

Write for information on "S" Monel and other Nickel-base alloys. Address:

THE INTERNATIONAL NICKEL COMPANY, INC.
67 Wall Street **New York, N. Y.**

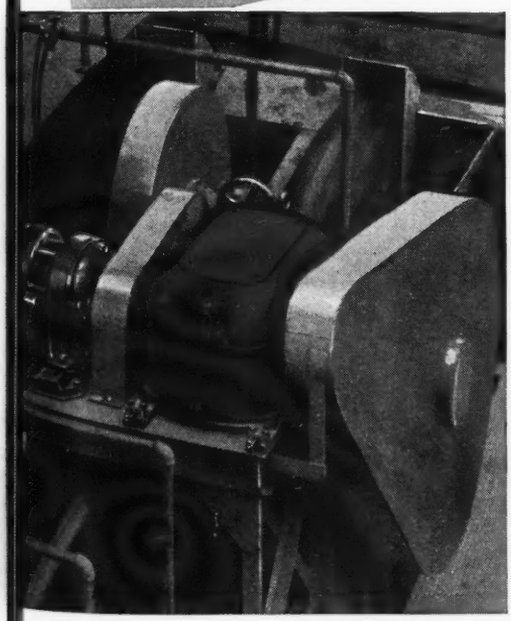


MONEL

"Monel" is a registered trade-mark of The International Nickel Company, Inc., which is applied to a nickel alloy containing approximately two-thirds nickel and one third copper.

YES! SAVES TIME, POWER, SPACE, MONEY

Read Why It Pays To Use The Sensational New Allis-Chalmers Vari-Pitch Speed Changer . . . the Unit That Gives You Smooth UP or DOWN Speed Changing . . . Provides Increased Producing Capacity For Your Machines . . . Gives You Greater Manufacturing Profits!



Here is one of the eight 22 hp Vari-Pitch Speed Changers on the job at Grand Coulee Dam. Working with Allis-Chalmers motors and starters, these Speed Changers operate rake-type sand classifiers, providing low-cost speed variations to suit changing needs.

YES! Saves Time! You can save valuable production time by using the new Vari-Pitch Speed Changer . . . no stopping production while making necessary speed changes . . . no time-wasting change-overs! Get the speed you want . . . instantaneously . . . by turning the hand wheel. Or if you desire, electrical fingertip control is provided . . . a flick of the switch gives you extra-fast speed changes!

YES! Saves Power! The Allis-Chalmers Vari-Pitch Speed Changer is a power-saver! Tests under load show amazingly high efficiency ratings. Dynamically balanced sheaves . . . anti-friction bearings . . . long-life Texropes—all help plug power leaks and assure low maintenance.

YES! Saves Space! Space is worth money . . . now you can save from 2/3 to 3/4 of the valuable space ordinarily used by bulkier transmissions. Double-shaft extensions let you place this compact, highly flexible unit in the most space-saving spot to do the most efficient work . . . at a cut in overhead costs!

YES! Saves Money! Be sure you understand the full money-saving importance of the Allis-Chalmers Vari-Pitch Speed Changer! It eliminates the need for costly multi-speed motors or separate change-overs for each new speed. Be sure you know what it means to have a variable speed transmission that operates easily . . . instantaneously . . . economically! Be sure you have the facts on this money-saving, profit-making performance!

Send today for Bulletin 1266 or call the district office near you. Find out how much you can save in Time . . . Power . . . Space . . . Money . . . by using the Allis-Chalmers Vari-Pitch Speed Changer!

1008

Texrope V-Belts • Duro-Brace Texsteel Sheaves • Texdrive Sheaves • Stock and Standard Cast Iron Sheaves • Vari-Pitch Speed Changers • Vari-Pitch Sheaves • Adjustable Pitch Diameter Cast Iron Sheaves • 2-3-4 Cast Iron Combination Sheaves • Paraline Automatic Motor Bases • Oil Field Drive Equipment and Drilling Rigs.

Belts by Goodrich

ALLIS-CHALMERS

MILWAUKEE · WISCONSIN

STACK DISCHARGE

cut to 10% of ash--and less!

THE important factor of stack discharge and the cost of reducing it present a minimum of concern to the operators of A-E-CO Taylor Stokers. First, because Taylor Stokers usually deliver 90% of the ash to the ash pit; and second, because the particles which do escape are of a type and size more easily collectible. Actually, Taylor Stokers operating under normal conditions with no fly ash collection systems are releasing less solids to the air than other types of fuel burning equipment utilizing elaborate and expensive collection systems. Call in an A-E-CO representative and investigate this fact. American Engineering Company, Aramingo Avenue, Philadelphia.

AE CO AMERICAN E

Illustration shows large crusher pit of a rotary discharge stoker.

GET THE FACTS ABOUT

- Reliability
- Capacity
- Maintenance
- Flexibility
- Efficiency
- Operation
- Adaptability
- Fuel Flexibility
- Refuse Disposal
- ★ Stack Discharge
- Space Requirements
- Obsolescence

THE A-E-CO Taylor Stoker

A-E-CO Water Walls

ENGINEERING COMPANY

A-E-CO Taylor Stokers, Water Walls, Ash Hoppers, Lo-Hed Hoists, Marine Deck Auxiliaries, Hele-Shaw Fluid Power

CORRECTLY ENGINEERED VALVES
IN THE RIGHT PLACE
Annual Round-Up
..OF LUN
LUNKENHEIMER
"FERRENEWO" and "RENEWO" VALVES
(REGULAR AND PLUG TYPE) VALVES
ARE "CORRECTLY ENGINEERED" FOR MAXIMUM ECONOMY ON THE JOB!
SEEING IS BELIEVING!
LUNKENHEIMER BRONZE GATE VALVES
ARE "CORRECTLY ENGINEERED" FOR MAXIMUM ECONOMY ON THE JOB!
LUNKENHEIMER
"KING-CLIP" GATE VALVES
ARE "CORRECTLY ENGINEERED" FOR MAXIMUM ECONOMY ON THE JOB!
SEEING IS BELIEVING!
LUNKENHEIMER
AIR CONTROL DEVICES
LUNKENHEIMER
BRONZE "N-M-D" VALVES
Sturdily Constructed for Long Life, plus Easily Renewable, Non-Metallic Discs for Low Upkeep
LUNKENHEIMER

KENHEIMER

"Engineered Superiority"

• • • • CATALOGING THE COMPLETE LINE OF "CORRECTLY ENGINEERED" VALVES FOR MAXIMUM ECONOMY ON EVERY JOB

While all the various types of Lunkenheimer valves and pipe line control devices required for the many widely divergent services throughout industry must of necessity differ substantially in design, material, and construction, they all have one common denominator . . . a basic *engineering superiority* which is easily discernible when you compare Lunkhenheimer products part-for-part with any other valve designed for like service. During the past months, therefore, we have used the pages of this magazine for the one purpose of highlighting those features of the principal items in our complete line which can readily be recognized as tangible evidence of improved design and construction . . . assurance of better, more dependable service on the jobs for which each is intended.

It is this "engineered superiority" which more than anything else accounts for Lunkenheimer's greater *ultimate* economy. Whether it be a matter of guarding against failure where experience shows trouble is most likely to occur, facilitating servicing to save you money on routine maintenance, or providing interchangeable parts to reduce stock room requirements . . . you can be sure that Lunkenheimer engineers have anticipated every possible factor to make your valve dollars go farther.

SEEING IS BELIEVING

We welcome, therefore, the opportunity presented by this Directory Issue of Power to "catalog" for your convenience, these typical Lunkenheimer products . . . all different in terms of service application, but identical in the kind of cost-saving service they are engineered to render . . . and invite you to follow our advertising in the regular issues of Power during the coming year as we similarly describe the "engineered superiority" of additional Lunkenheimer products.

CORRECTLY ENGINEERED VALVES
IN THE RIGHT PLACE
Offering a Wide Variety of Throttling and Needle Point Types for Every Service • • •
LUNKENHEIMER VALVES
FOR INSTRUMENT LINES, DRAINS AND BY-PASSES
• • • ARE "CORRECTLY ENGINEERED" FOR MAXIMUM ECONOMY ON THE JOB!
SEEING IS BELIEVING!
LUNKENHEIMER

For complete and detailed information on all Lunkenheimer products, send for General Catalog 78. We will include our handy "Guide," which makes selection easy by grouping valves, boiler mountings, and lubricating devices according to pressures, temperatures, and service applications.

ESTABLISHED 1862

THE LUNKENHEIMER CO.

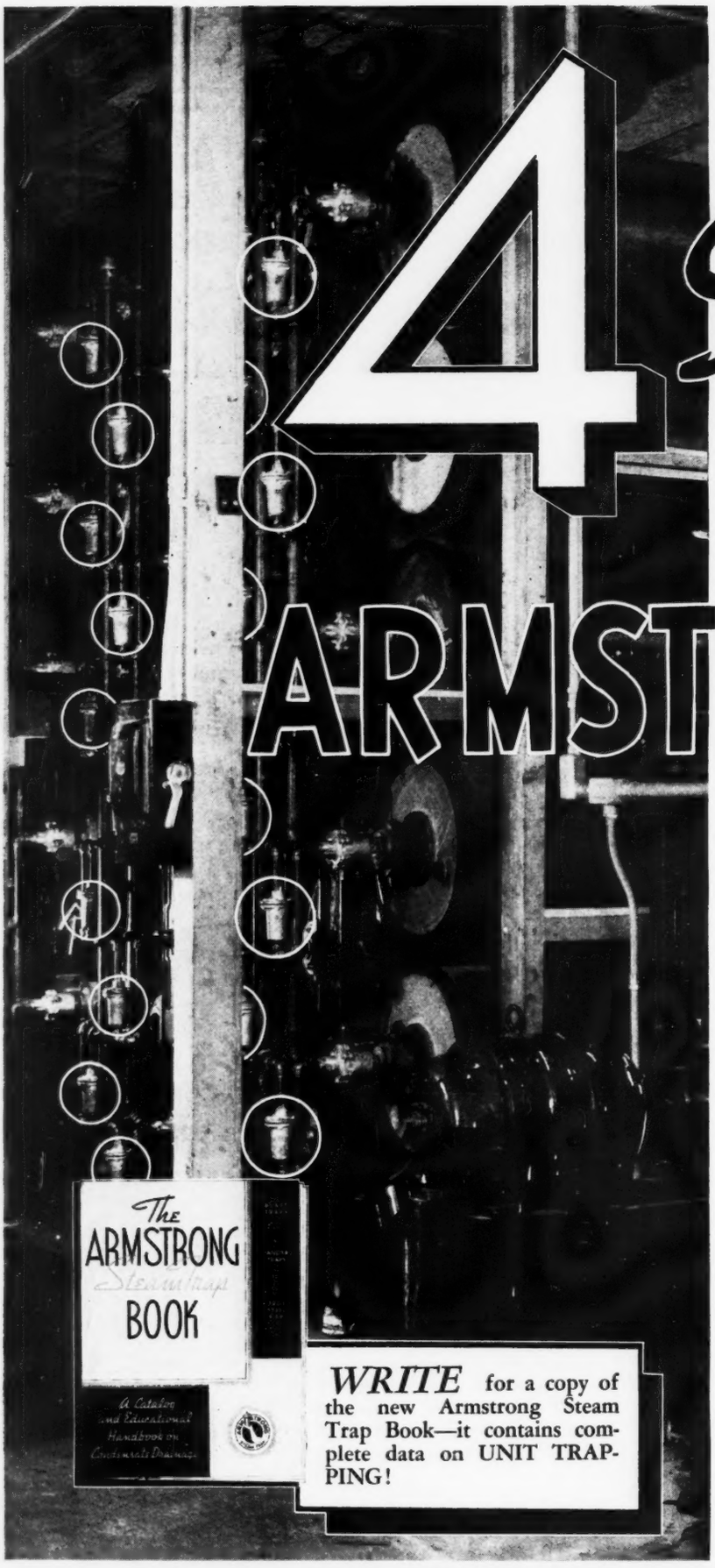
"QUALITY"

CINCINNATI, OHIO. U. S. A.

NEW YORK CHICAGO
BOSTON PHILADELPHIA

EXPORT DEPT. 318-322 HUDSON ST., NEW YORK

14-10-42



4 Big Savings with ARMSTRONG

1. TIME SAVINGS

MEAT PACKER — Elliot Packing Co. of Duluth, Minnesota, is well aware of the fact that processing costs vary in almost direct proportion to time in process. For this reason, the Elliot production department became an ardent booster for ARMSTRONG UNIT TRAPPING when it was discovered that Elliot cooking kettles so trapped did as much work in 3½ hours as had been done previously in 8 hours.

CANNER — Bulman's Ltd., Vernon, B. C., is a widely known plant for canning and dehydrating fruits and vegetables in the famous Okanagan Valley of British Columbia. Modernization of this plant recently included a complete installation of ARMSTRONG UNIT TRAPPING. Formerly, it took 10 minutes to bring 240 gallon kettles to a boil; now, they do it in 7 minutes — a 30% time saving! Handsome steam savings were also secured by eliminating blow-thru methods.

WRITE for a copy of the new Armstrong Steam Trap Book—it contains complete data on UNIT TRAPPING!

ARMSTRONG MACHINE WORKS

TRAPPING TIPS:

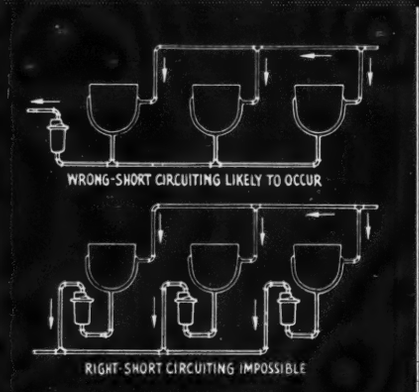


Fig. 1—A cold kettle will condense more steam and have lower outlet pressure than a hot kettle. The result is back-flow into the cold kettle—pocketing air and condensate.

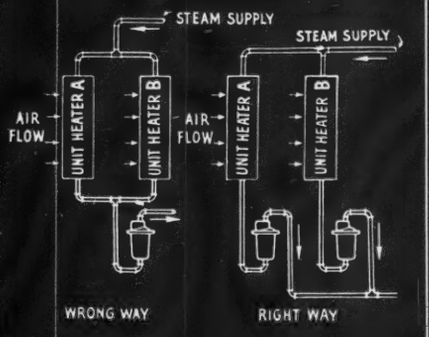


Fig. 2—Outlet pressure for Heater B will be higher than for Heater A until enough air accumulates inside A to reduce its condensation rate to a par with B.

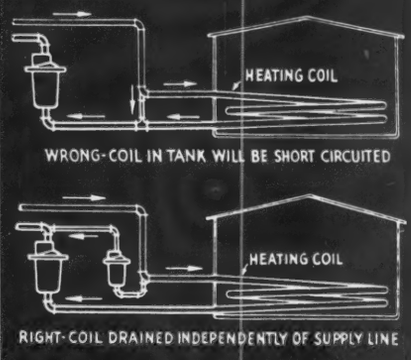


Fig. 3—Never try to drain the steam header with the same trap that is supposed to drain the unit being supplied with steam. Condensate and air will be pocketed in the heating unit.

UNIT TRAPPING!

2. FUEL SAVINGS

HOTEL—Mr. George Trail, Chief Engineer of the Lord Baltimore Hotel, of Baltimore, Md., has recently received wide-spread mention for a 2 year program of efficiency engineering that cut steam costs 13%. One of his important steps was to apply ARMSTRONG UNIT TRAPPING to all steam heated laundry and kitchen equipment.

FACTORY HEATING — In answer to the question "How good is ARMSTRONG UNIT TRAPPING for low pressure heating systems?", Armstrong's Representative in Milwaukee reports on an installation of some 26 small Armstrong traps for the Northwestern Store Equipment Corp. Exhaust steam is used for the unit heaters and wood drying kilns at a pressure of about 2½ lbs. In the first year, the traps were credited with saving 170 tons of coal!

3. MAINTENANCE SAVINGS

CERAMIC PLANT — "20 days per month for trap and pipe maintenance reduced to one day per month" is the report of the R. Thomas & Sons Co., Lisbon, Ohio, after installing 66 Armstrong traps to drain the individual coils of drying rooms and other equipment used in the manufacture of porcelain insulators.

SHOE FACTORY — Brown Shoe Co. has over 20 factory buildings in and around the St. Louis area, and for years, have used Armstrong traps for service above 15 lbs. pressure. Some time ago, the Chief Engineer got a GOOD IDEA for cutting maintenance costs. He found that unit repair costs for his low pressure heating system traps were running considerably higher than for the Armstrong traps on harder service. By using Armstrongs for low pressure, he now gets low maintenance costs for all service.

4. CAPITAL INVESTMENT

LAUNDRY—In Honolulu, the American Sanitary Laundry recently found itself very much in need of more boiler capacity. It looked like an addition would have to be built on the power plant. Then 62 Armstrong traps were put in on a complete UNIT TRAPPING program. Heating efficiency was improved . . . Steam leaks were stopped . . . And the boiler plant then had plenty of capacity without enlargement.

FURNITURE MAKER — Union Chair Co. of Union City, Pa., makes a lot of wood chairs with bent backs —in fact, some time ago, business became so good that more bending presses were needed in a hurry. Somebody suggested that the existing presses might do more work if UNIT TRAPPED with Armstrongs. The idea worked: formerly, it took 60 minutes press time to bend a batch of backs; now, it takes only 30 minutes.

812 MAPLE STREET, THREE RIVERS, MICH.

SILICA
45
40
35
30
25
20
15
10
5
2.5
SILICA PPM IN SOLUTION
INITIAL SILICA-46.4 PPM
TREATMENT-180 PPM
1
TIME-HRS.
BEAT SILICA SCALE...use

REDUCED from 46.4 to 1.5 with Allis-Chalmers Silimite!

Large Chemical Plant Uses New Allis-Chalmers SILIMITE Treatment to Solve Difficult Silica Problem... Reduces Silica from 46.4 ppm to 1.5 ppm... Cuts Treatment Costs More Than 50%!

FOR SEVERAL YEARS, a large American chemical plant was plagued with silica troubles — silica scale in the boilers . . . excessive blowdown . . . costly turbine blade scale deposits.

Numerous treatments were attempted — unsuccessfully — including magnesium sulfate, iron sulfate, zinc sulfate, and aluminum sulfate. Costs of these ineffective treatments were from four to six cents per 1,000 gallons of water treated.

A Treatment That's New, Different!

Then, recently — SILIMITE was tried! Here was something new . . . different . . . a way to remove silica externally in connection with the usual lime-soda softening process . . . a method that required no expensive equipment.

A test was made. And in one hour, as shown on the chart, the rate of silica removal plummeted from 46.4 ppm to 1.5 ppm. What's more, there was no increase in total solids . . . and costs which had been four to six cents per 1,000 gallons with the old ineffective treatments dropped to 1.7 cents with Allis-Chalmers SILIMITE.

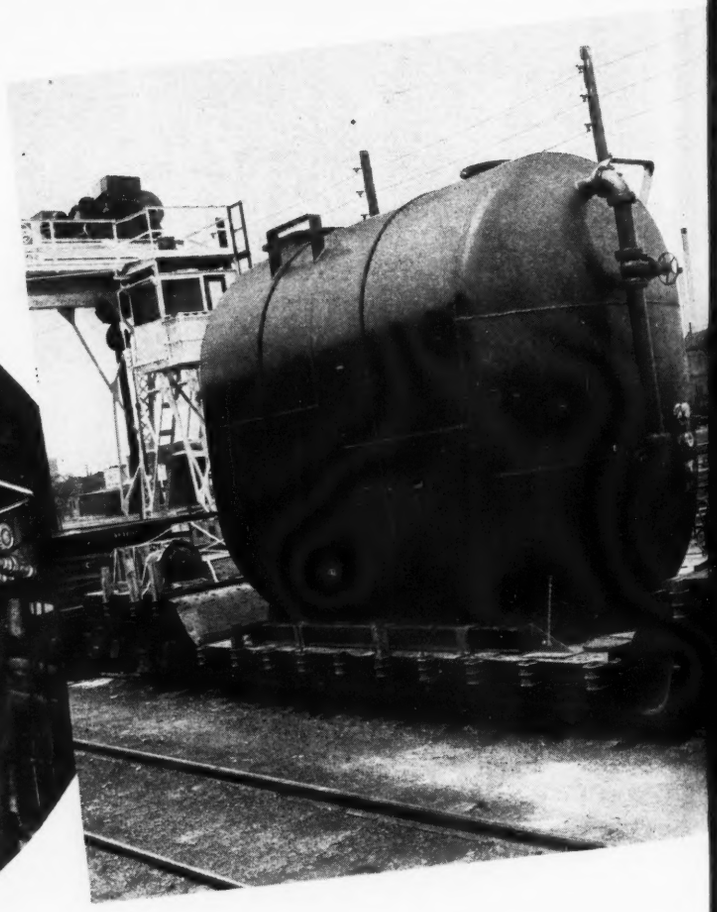
Find Out About SIMILITE!

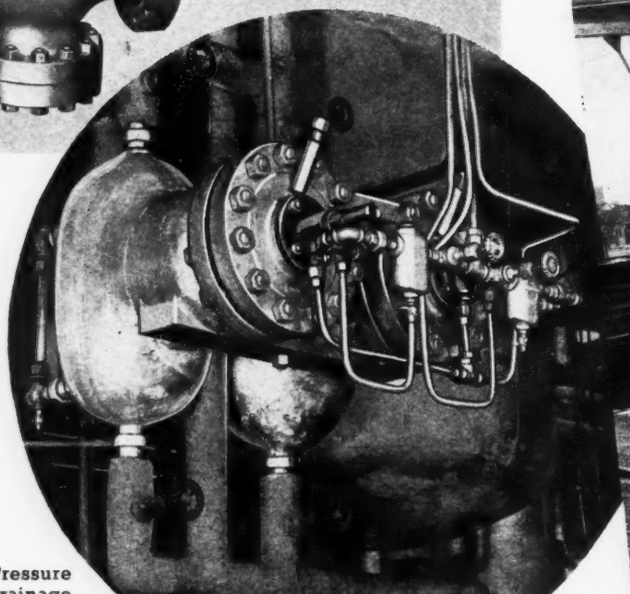
That's why, if you have a silica problem in your plant, it will pay you to get the story about SILIMITE, the new Allis-Chalmers proved silica treatment. To find out how it can help you, write for full details to Feedwater Division, Allis-Chalmers, Milwaukee, Wisconsin. A 1324

e ALLIS-CHALMERS SILIMITE!

24-hour-a-day Defense...

• Swartwout Feed Water Regulation unit, air actuated, with manual control — Municipal Plant, City of Cleveland, Ohio





• High Pressure Heater Drainage Controls—Columbus & Southern Ohio Electric Co., Columbus, Ohio

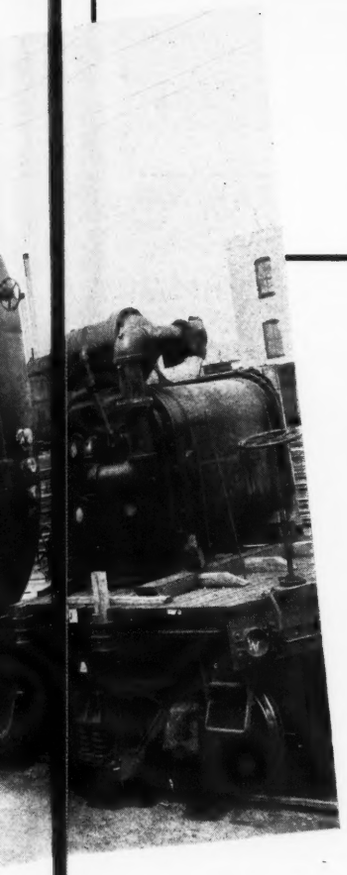
Feed Water Regulators • Pump Governors • Feed Water Heaters
Master Controls • Reducing Valves • Separators • Exhaust Heads

Swartwout

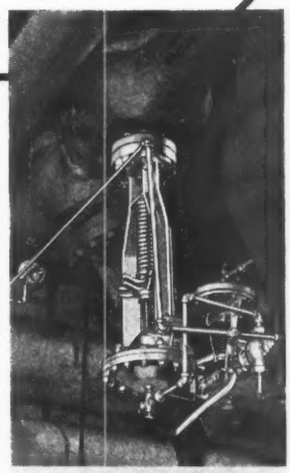
•Power Plant Equipment•

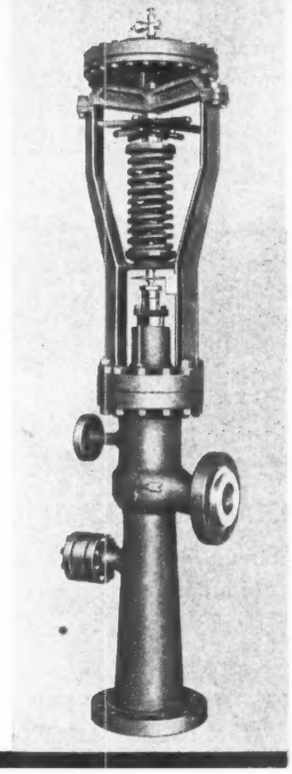
against costly power failure that can wreck your critically important delivery schedules

Hundreds of industries depend safely on Swartwout Automatic Power Plant Controls to keep "defense" wheels moving . . .



• Swartwout Metering Deaerating Heater, extra large storage — Lowry Field, Denver, Colorado

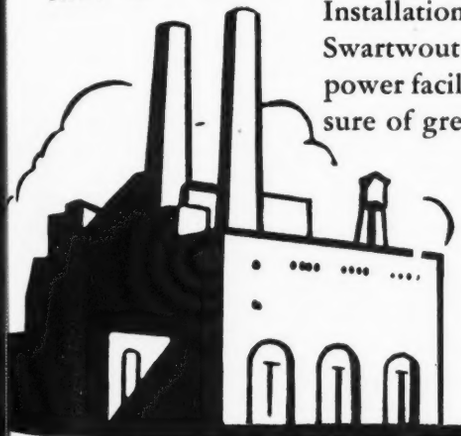




NOW, more than ever before, your reputation for safe continuous operation and your ability to meet production entrusted to you depend on assurance of smooth dependable flow of power. How Swartwout Power Plant Equipment controls feed water, steam pressures and temperatures and banishes the anxiety of man-operated regulation, is a story it pays every power engineer to know.

Day after day, year after year, Swartwout Standard and Special Controls harness high and low pressures, marshall vital forces at low operating cost and enormous saving of time and worry. Unusual safety provisions applied in a thousand unique situations prove the sound flexibility which Swartwout Engineers have developed in over 35 years of painstaking research and application to the power field.

Ask any consulting engineer, and power men everywhere — they take personal pride in their Swartwout Installations. Make a note right now to investigate Swartwout Equipment so that when you build new power facilities or revamp present plant you can make sure of greater safety and efficiency.



The Swartwout Company

18501 EUCLID AVE., CLEVELAND, OHIO

★ ★ ★

UPPER RIGHT: Emergency Bypass Valve, around closed heater. **LOWER RIGHT:** Combination Reducing Valve and Desuperheater

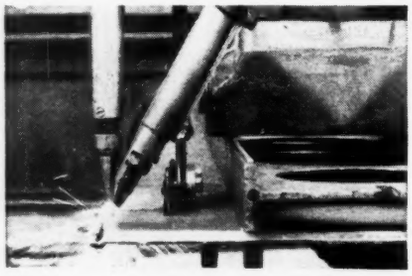
How Linde Products and Processes

are used to modernize power systems and maintain them under increased load

With increased production calling for more power-service capacity, the Linde processes shown here can help you keep your generating and distributing equipment in efficient condition to stand the load. They can help rebuild your system for increased capacity, with a minimum of shut-down time. They are extremely useful in the installation of new power units and piping.

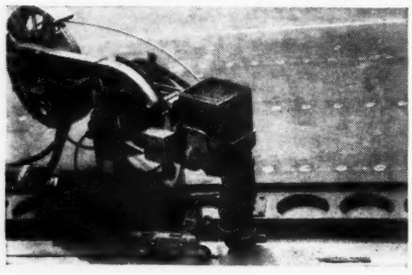
FLAME-CLEANING

Oxy-acetylene equipment can be used to remove scale from structural steel, castings, or forgings—quickly and economically. *Applied to metal before painting, this process helps prevent flaking of the paint at a later date.*



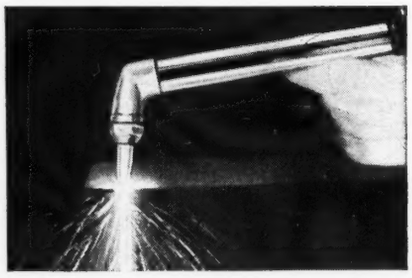
MACHINE FLAME-CUTTING

This process makes possible the rapid and economical production of steel shapes from stock of practically any commercially used thickness—or from stacks of plate. It is effectively used, too, for plate-edge preparation, prior to welding. For work on the job, small portable machines are available. For shop fabrication, larger stationary machines are often used advantageously. *This process is particularly valuable because you can avoid delays by fabricating what you need as you need it from stock steel.*



UNIONMELT WELDING

This remarkable electric process—available only from Linde—makes high-quality, one-pass welds in thin or heavy metal at remarkable speeds, with no flash, glare or sparks. It is particularly well adapted to production of derrick booms or other heavy structural members, fabrication of pressure vessels, fabrication of large diameter pipe, and similar work. *The "human element" is removed as a factor in getting good welds with Unionmelt welding, because once started, the weld progresses automatically.*

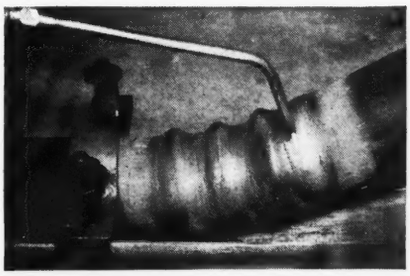


HAND-CUTTING

This process is used for cutting structural members to length, for scrapping operations, for cutting off concrete reinforcing bars, for cutting pipe, and for producing small steel parts used in maintenance and fabrication work. *With special nozzles, rivet removal by flame-cutting is made safer, faster, and less expensive.*

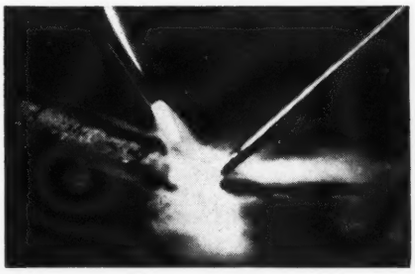
LINDE OXYGEN, HYDROGEN, NITROGEN • PREST-O-LITE ACETYLENE • UNION CARBIDE

The words "Linde," "Prest-O-Lite," "Union," "Oxweld," "Prest-O-Weld," "Purox," "Haynes Stellite," and "Unionmelt" are trade-marks.



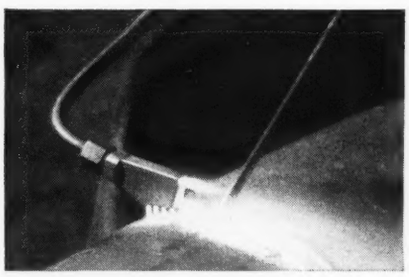
HEATING AND BENDING

The intense, easily-controlled heat of the oxy-acetylene flame makes it valuable for bending, straightening, and forming. *Wrinkle-bending, for example, produces smooth, sweeping pipe bends, without thinning the pipe wall or creating internal obstruction to flow.*



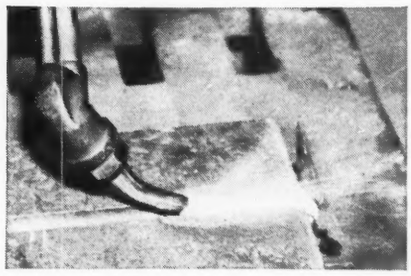
OXY-ACETYLENE WELDING

Because the oxy-acetylene flame is the hottest known, practically any metals—similar or dissimilar—can be joined so that the welds are stronger than the base metals themselves. *This universal process saves hundreds of thousands of dollars annually in maintenance and repair work alone.*



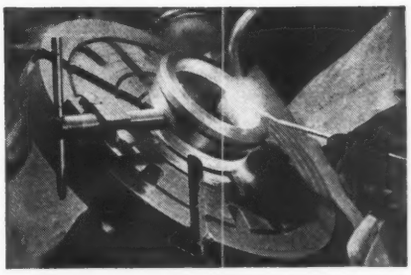
LINDEWELD PROCESS

Pipe or heavy plate can be joined by this process with impressive savings of time and materials. It is applied with an easily learned, special technique, using multi-flame welding heads. *Welds in pipe joined by the Lindeweld process are strong and ductile — stay leakproof and maintenance-free indefinitely.*



GOUGING

This relatively new Linde process rapidly cuts out a "groove" of surface metal, without harm to adjacent areas. It is used for removal of faulty or temporary welds, for correction of structural defects, for alteration of design on forgings or castings, and to provide clearance for moving parts. Applied by machine, gouging nozzles are valuable for plate-edge preparation. *This easily used process saves hours of grinding or chipping and sometimes salvages parts that otherwise would have to be scrapped.*



HARD-FACING

Parts subjected to severe abrasion, impact, or corrosion can be made to *last many times longer by applying Haynes Stellite alloys to the wearing surfaces.*

OXYGEN LANCE

To quickly sever extremely heavy sections of iron or steel—to remove gates or risers from heavy castings *—the oxygen lance is used with considerable savings in time and money.*

and Linde can help you use them

Linde can supply *all* your oxy-acetylene needs—oxygen, acetylene, carbide, apparatus, and supplies—wherever you operate. By buying from Linde, you can centralize your source of supply and thereby effect important savings.

Even more important, Linde can furnish customers practical, on-the-job help in applying the processes shown here successfully, and can help hold down process costs.

If you want to know more about these processes, or about Linde's ability to help you use them to save time and money, in both power and production operations, ask Linde.

THE LINDE AIR PRODUCTS COMPANY

Unit of Union Carbide and Carbon Corporation

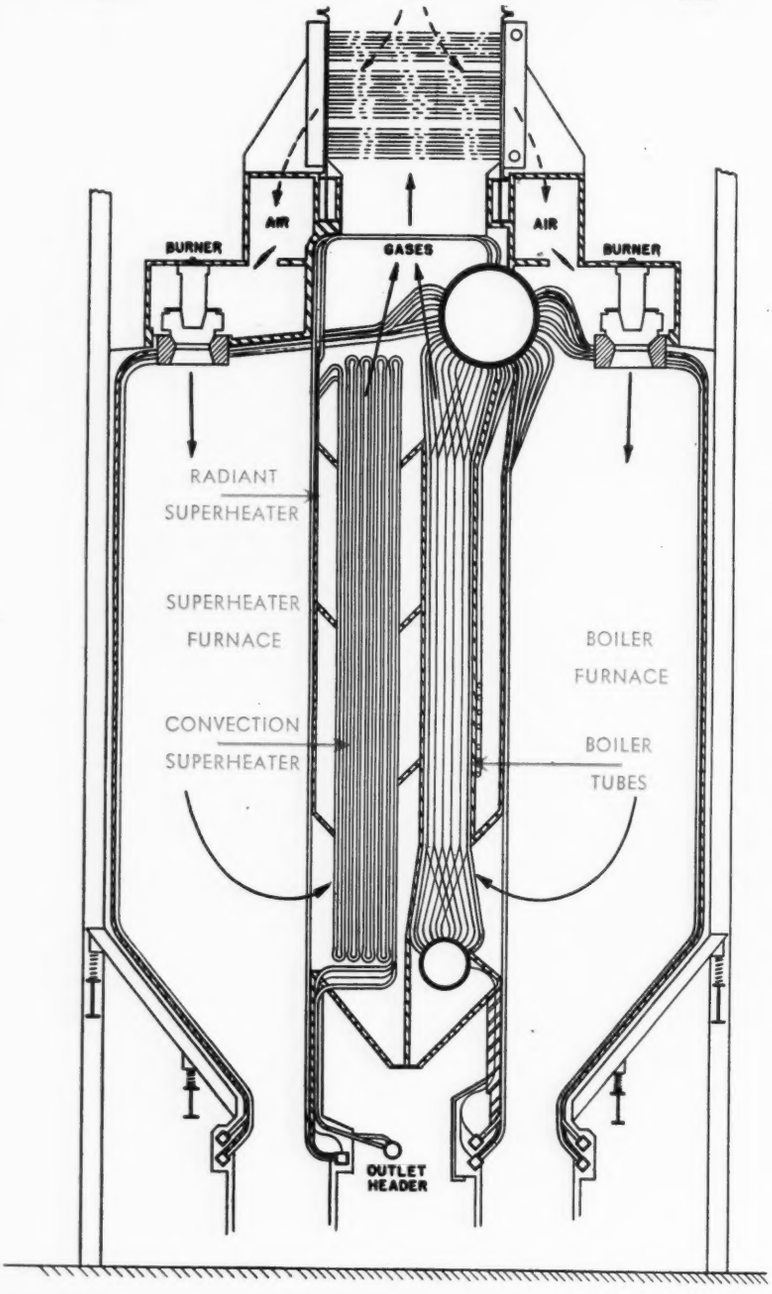
30 E. 42nd St., New York, N. Y. UCC Offices in Principal Cities

In Canada: Dominion Oxygen Company, Limited, Toronto

OXWELD, PREST-O-WELD, PUROX APPARATUS • OXWELD SUPPLIES • UNIONMELT WELDING

Twin Furnace

Separate Superheater



450,000 lb. per hour
1,550 lb. per sq. in.
950 deg. F. S. T.

Twin furnace design showing steam generating furnace at right, with gases passing over boiler tube surface; superheater furnace at left, with gases passing over convection superheater surface. Steam from boiler drum flows down through radiant superheater tubes to a header at the bottom of setting, then up again through alternate rows of tubes to the top where it enters the convection superheater. Gases from both furnaces join before passing through the economizer and air preheater.

By dividing the furnace volume into two furnaces using radiant-heat-absorbing division walls, additional furnace cooling surface has been installed. This division adds two walls with an increase of 25 to 30 per cent in water cooled surface per cubic foot of furnace volume.

FW FOSTER

STEAM GENERATORS

Furnace Type

Four twin furnace steam generators of this type are now under construction for prominent central stations, requiring high pressure, high temperature and wide range of output. Their essential characteristics include:

1. **More water cooling in furnace:**
   - **Minimum slagging in boiler and superheater**
   - **Lower servicing cost**
   - **Higher furnace efficiency**

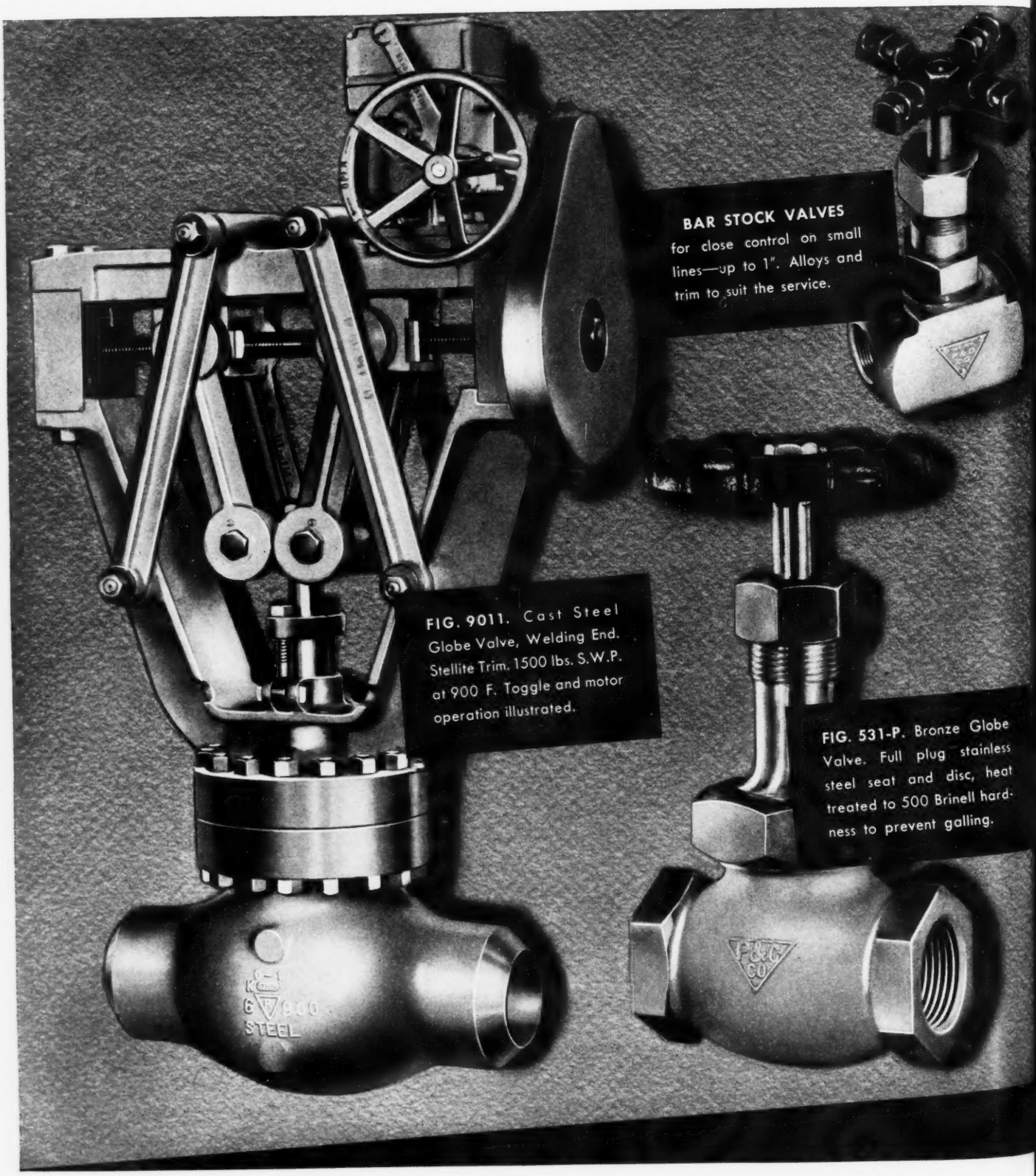
2. **Superheat control over full Load-Range:**
   - **Constant steam temperature over entire load range**
   - **Higher turbine efficiency at lower loads**

3. **No firing of superheater furnace while starting up:**
   - **Shorter time onto line**
   - **No cooling device for superheater**

FOSTER WHEELER CORPORATION
165 Broadway, New York, N. Y.

WHEELER

MEETING THE CALL FOR


BAR STOCK VALVES
for close control on small lines—up to 1". Alloys and trim to suit the service.
FIG. 9011. Cast Steel Globe Valve, Welding End. Stellite Trim. 1500 lbs. S.W.P. at 900 F. Toggle and motor operation illustrated.
FIG. 531-P. Bronze Globe Valve. Full plug stainless steel seat and disc, heat treated to 500 Brinell hardness to prevent galling.
STEEL
P&G CO

PRODUCTION

NOW more than ever, you have to meet the call for *uninterrupted*—and *low cost* K.W. production.

We believe our Engineers can be of real service to you whenever valves are considered. There is scarcely a phase of present day operations with which they are not in intimate touch.

The valves illustrated are but a few of the many in our line available for every power plant requirement. So, whenever valves are being discussed, you will find it well worthwhile to get a recommendation from Reading-Pratt & Cady.

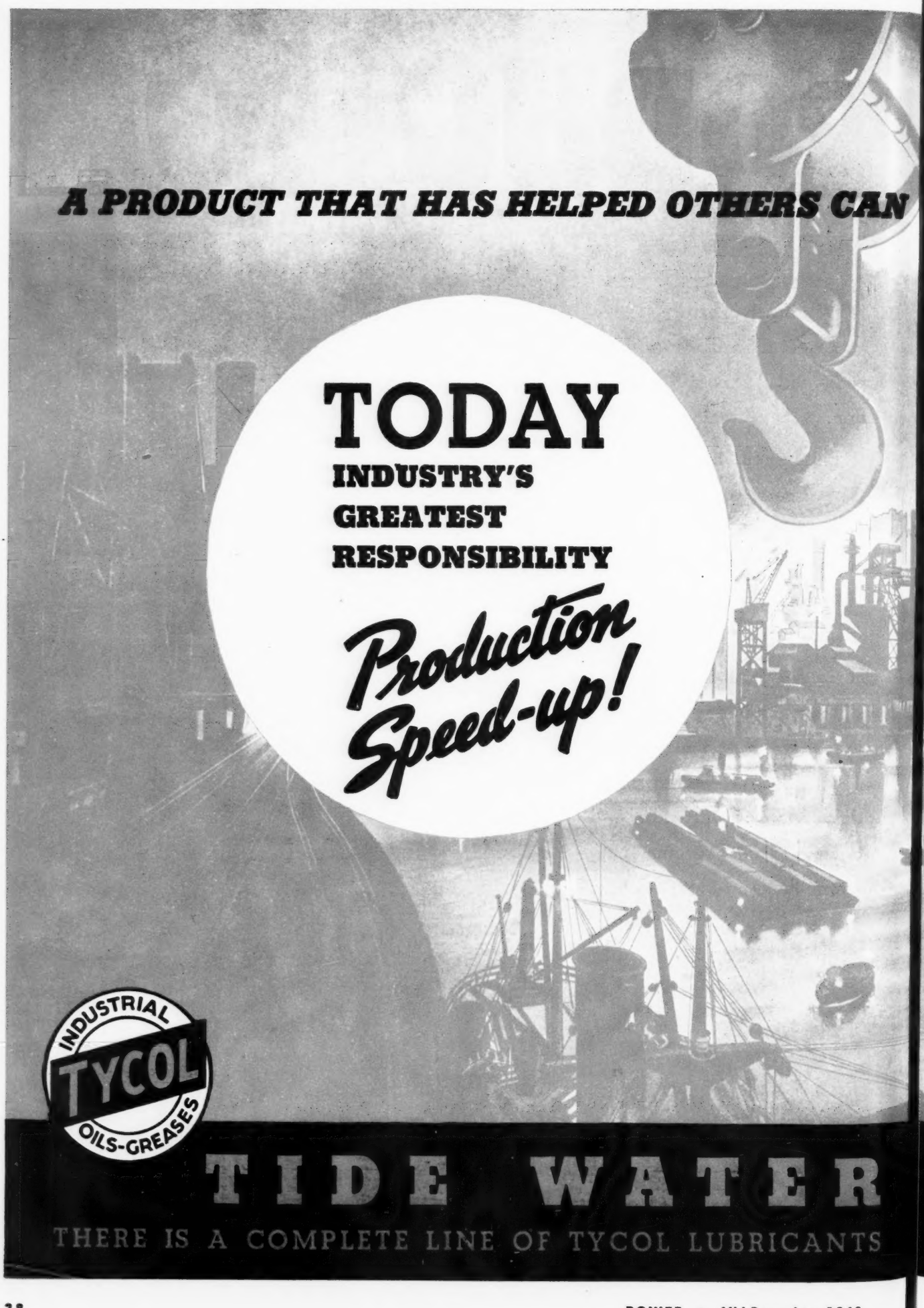
TRADE MARK ACCO

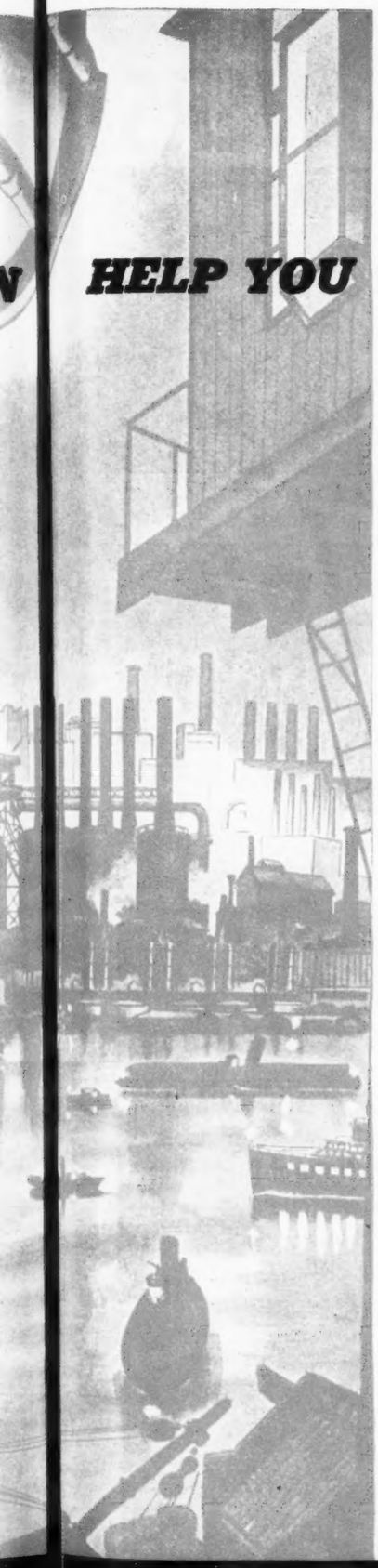
FIG. 1501. Cast Steel Gate Valves. Stainless Steel Trim. 150 lbs. at 500°F. Flanged end illustrated.

FIG. 186. Iron Body, Bronze Mounted Gate Valve. 75 lbs. to 100 lbs. O.W.G.

READING-PRATT & CADY
DIVISION · · READING, PENNSYLVANIA

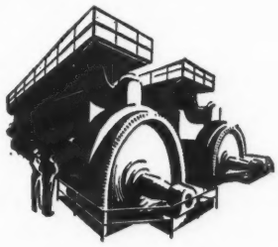
AMERICAN CHAIN & CABLE COMPANY, Inc.


A PRODUCT THAT HAS HELPED OTHERS CAN
TODAY
INDUSTRY'S
GREATEST
RESPONSIBILITY
Production
Speed-up!
INDUSTRIAL
TYCOL
OILS-GREASES
TIDE WATER
THERE IS A COMPLETE LINE OF TYCOL LUBRICANTS



HELP YOU

FOR THESE TWO DIESELS



. . . . the waste of frequent changes, carbon and sludge was proved needless by . . .

TYCOL DIESEL OIL

"The power for our plant is supplied by two 45 h.p. Diesel engines," this engineer explained. "These are lubricated with Tycol Diesel Oil, an oil we have been using for almost 3 years. We feel that it is doing an outstanding job."

"The room temperature is usually around 120°. This, plus the fact that the Diesels are running with an almost capacity load for 14 hours a day, demands an exceptionally good oil. We have found that ordinary oil under such circumstances breaks down and runs like water. We would get overheating with damage to cylinders and bearings."

"With Tycol Oil we now find on opening the engine that the rings are not stuck with hardened carbon and are not difficult to replace. We also find that the crankcase is almost entirely free from sludge in spite of the tough lubricating job."

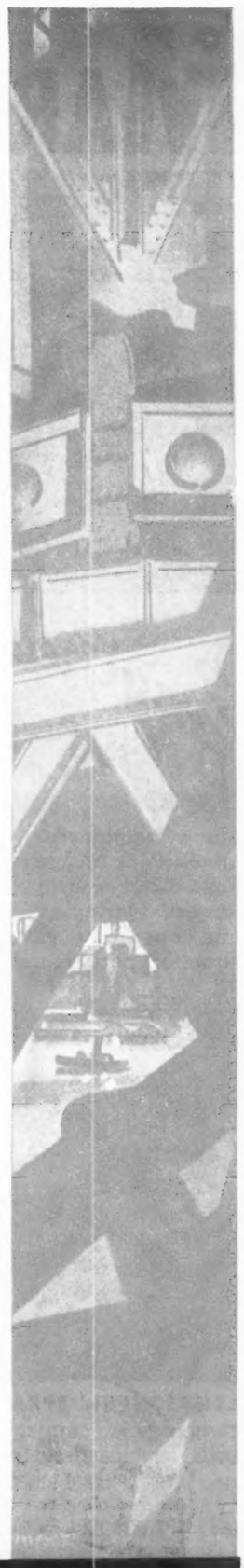
Regardless of operating conditions, on Diesels large or small, Tycol Diesel Oil is the answer. It assures maximum performance per gallon of lubricant. Our representatives will be glad to assist you in selecting the proper Tycol Oil "engineered to fit your needs." Write for full details.

TIDE WATER ASSOCIATED OIL COMPANY

EASTERN DIVISION

17 Battery Place • New York, N. Y.

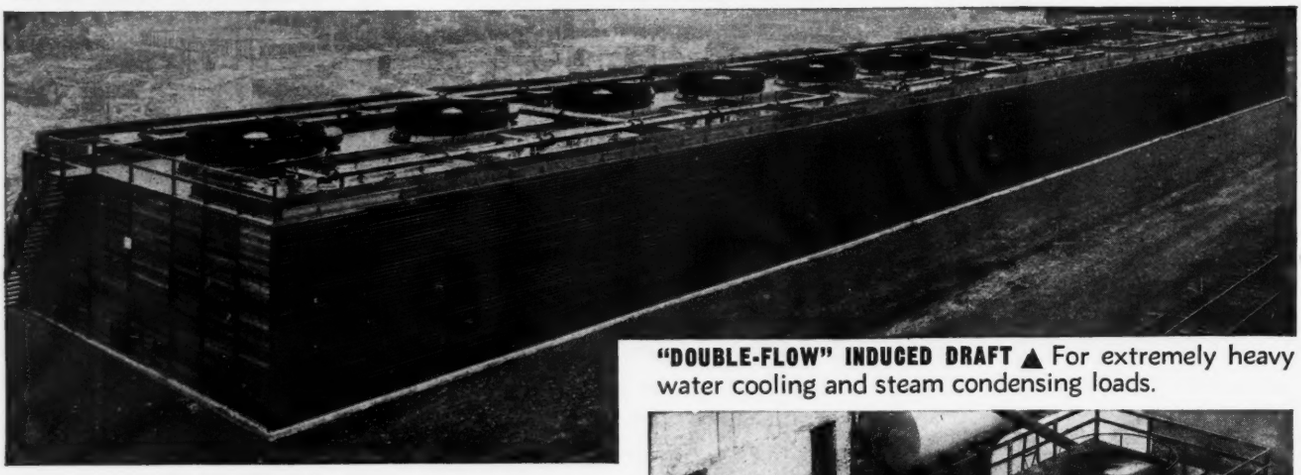
Regional Offices: Boston, Philadelphia, Pittsburgh, Charlotte, N. C.



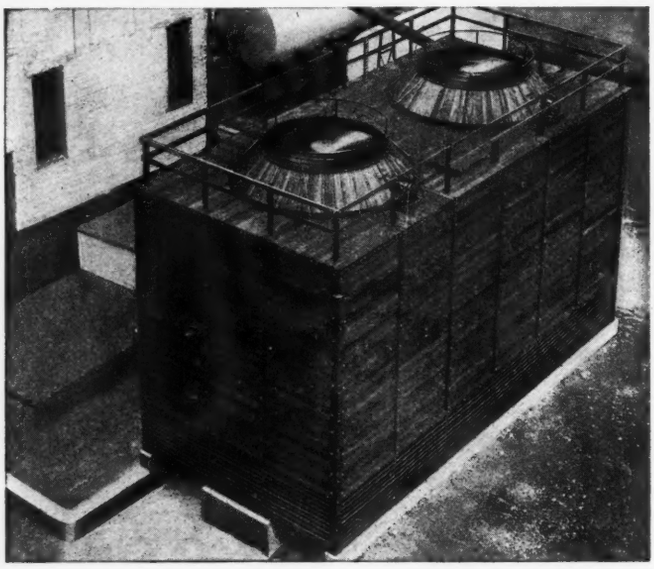
DIESEL OIL

SCIENTIFICALLY ENGINEERED FOR EVERY INDUSTRIAL USE

MARLEY COOLING TOWERS



"DOUBLE-FLOW" INDUCED DRAFT ▲ For extremely heavy water cooling and steam condensing loads.



Even Greater Performance and Economy at Less Cost!

Marley engineering has made the cooling tower's advantages and savings available to an almost unlimited range of applications from very small to the largest. Marley's well known structural, mechanical and operating characteristics bring owners unequalled performance, dependability and long life.

"STANDARD" INDUCED DRAFT ▲ For any capacity in any kind of service. Redwood or steel.

ATMOSPHERIC SPRAY TYPE ▲ For cooling engines, compressors, condensers, etc. Also equipped with coils for closed-system or "indirect" cooling.

also: ATMOSPHERIC DECK TYPE TOWERS for all heavy industrial water cooling services.

and: SPRAY PONDS and all accessories including louvered fence for prevention of wind drift.

Marley *Non-Clog* SPRAY NOZZLES

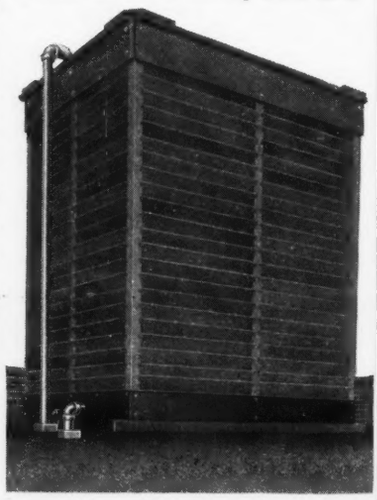
with Patented Side-Injection

ALL TYPES for Air Washers, Brine Spraying, Atmospheric Condensers, Cooling Towers, Humidifying, Ice-Melting, etc. Many sound reasons why they lead in sales and installed capacity.

And Now a Great New Line of Natural-Draft Units at Prices Even Lower Than "Home Made" Devices—

for Cooling Engines, Compressors, Condensers, Molds, Etc.

Here is the new Marley "Series 100"—all factory built in a complete range of sizes—carried in stock for immediate delivery—fully guaranteed for quality and performance—and backed by a well-known, responsible engineering and manufacturing organization, the largest and most widely experienced in the business.



RETAILS AS LOW AS

$70.00 COMPLETE

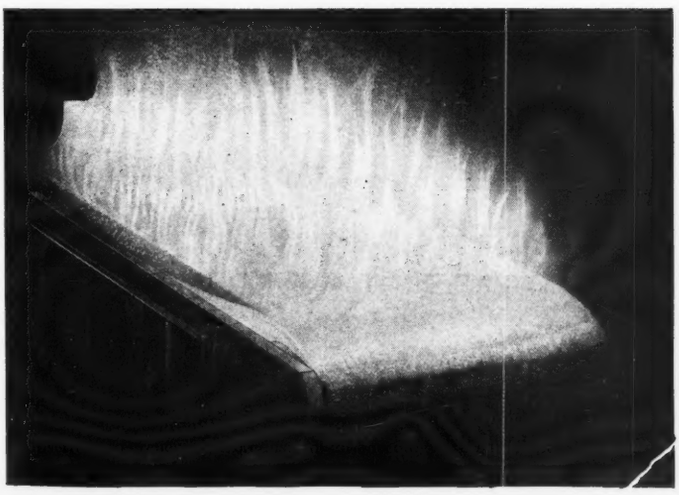
FREIGHT PAID

THE MARLEY CO., 3001 FAIRFAX RD., KANSAS CITY, KANS.

At Republic Rubber Youngstown, Ohio

A 715 H.P. STOWE STOKER handles load swings from 39,000 to 57,000 lbs. of steam per hour quickly, and with practically no fluctuation in boiler pressure

Installed with a 4 drum B. & W. boiler in 1938, the Stowe Stoker at Republic Rubber carries a widely fluctuating processing load in its entirety and all of the turbine load as well. But let the figures tell the story. The larger chart shows the steam flow for processing purposes only. Note the fluctuations just after 7 o'clock, the big jumps at 9:15, 10:30, 11:30, and just after 3. Then look at the left hand chart. It shows that the boiler pressures are practically constant in spite of these wide load fluctuations. That's the kind of operation Republic Rubber and other owners are getting with their Stowe Stokers.



Featuring a unique construction that is entirely different from underfeed or chain grate design, Stowe Stokers maintain the fuel bed at even depth side to side and front to rear. Stowe Stokers minimize draft problems and avoid formation of objectionable clinkers, permitting extremely rapid load swings. They eliminate "fall-offs" for fire cleaning and exposure of bare grates. High rates of burning and high efficiencies are secured at all ratings. They produce more steam, cheaper.

We will welcome an opportunity of proving these claims, or better yet, take advantage of our offer to arrange inspection trips and see for yourself, first hand, what Stowe Stokers are doing, and how thoroughly they are doing it.

THE JOHNSTON & JENNINGS CO.

DETROIT — 878 Addison Road, CLEVELAND, OHIO — CHICAGO

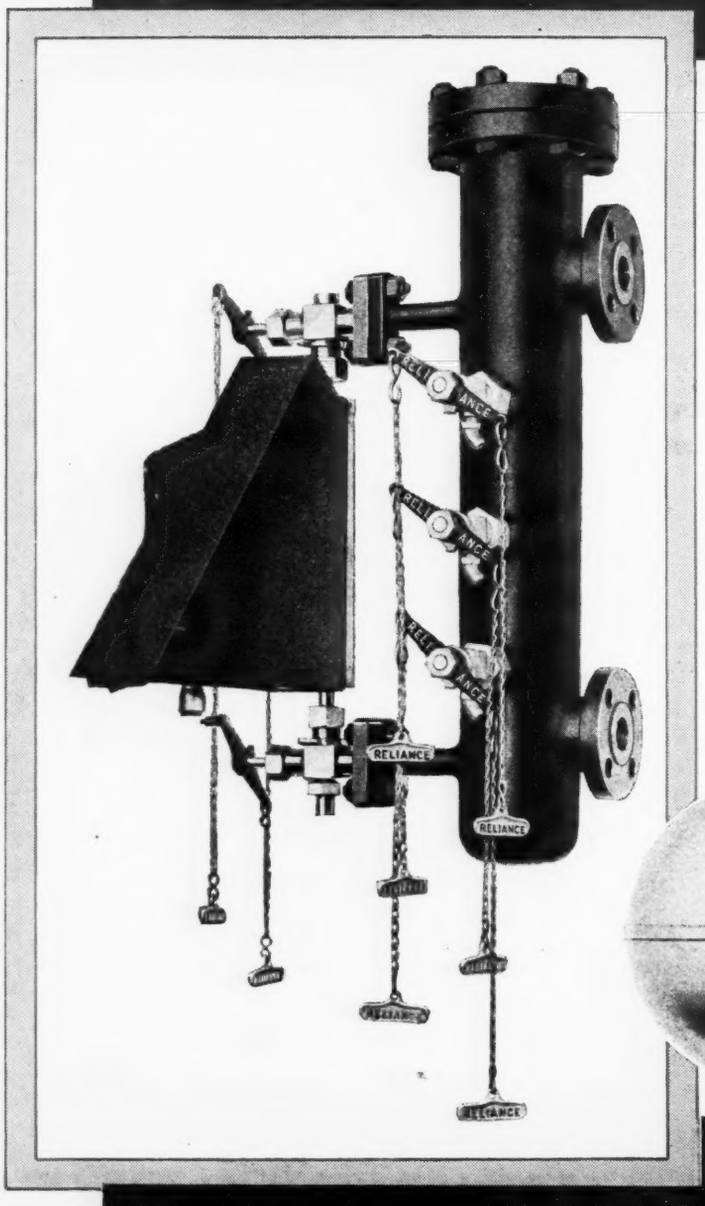
Engineering and Sales Representatives in
New York • Pittsburgh • Kansas City • St. Louis

STOWE STOKERS

★ ★ GIVE YOU MORE STEAM FROM LESS COAL ★ ★

More than 200,000 users have proved that

When Reliance Safe
it Safeguards Your Produc

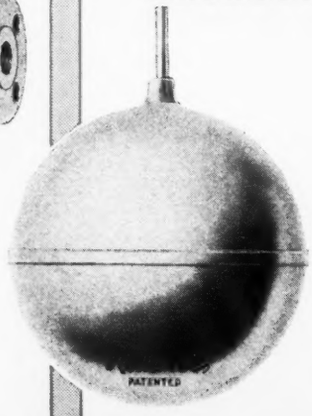


RELIANCE SAFETY TEAM

SOUND CHECK ✓ ALARM Water Column

SIGHT CHECK ✓ EYE-HYE Remote Gage

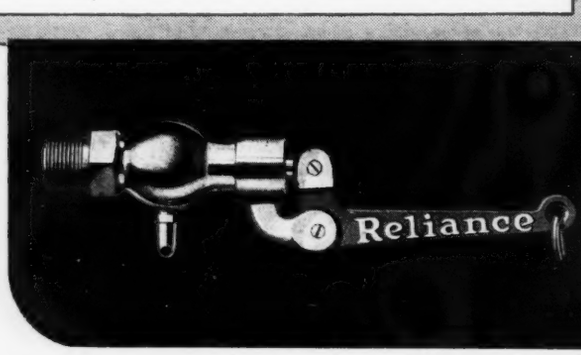
How the Reliance Safety Team assures efficient boiler water levels and uninterrupted operation

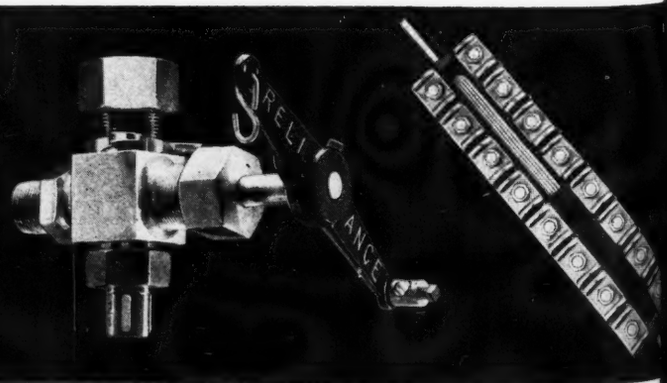


The powerful, highly buoyant Reliance Floats of fused monel are sensitive to slight water level variation — assure positive response.

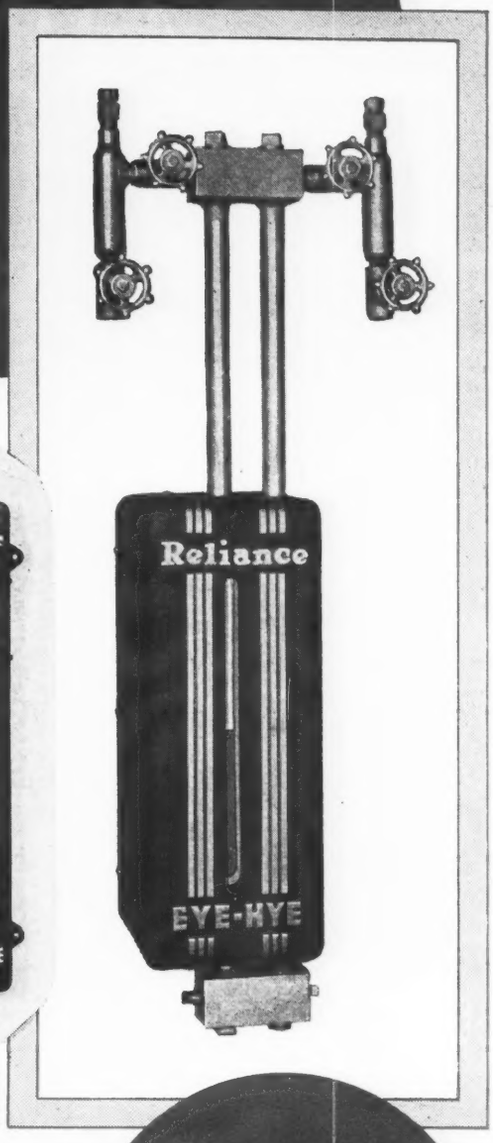
* * *

Reliance Accessories include Spring Gage Cock, Bronze Gage Valve, Prismatic Gage Insert, Micasight Gage Insert, Forged Steel Gage Cock, Forged Steel Gage Valve





e guards Your Power
c tion and Earnings



EYE-HYE for precise reading of heater tanks and other vessels

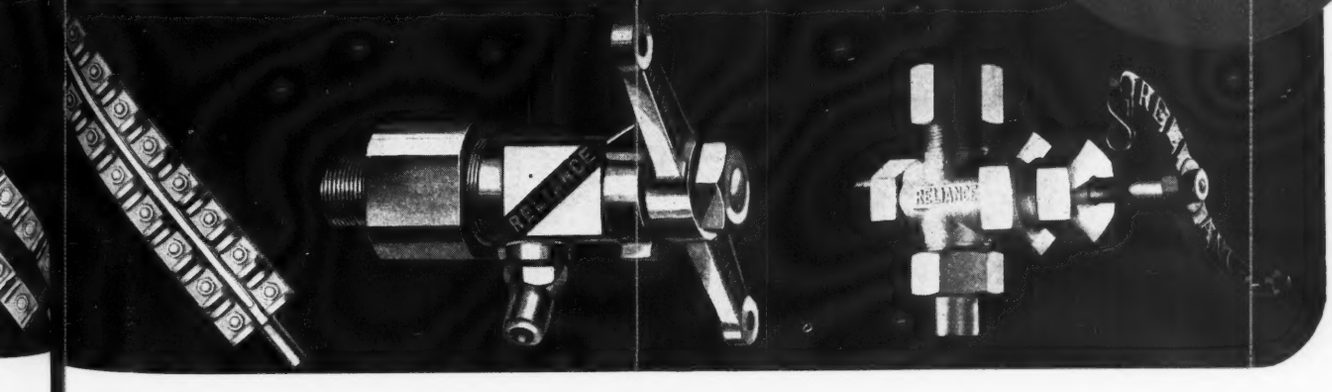
EVEN though you may have the "last word" in boiler feed water control, boiler codes and your common sense dictate the need for *extra checks* on water levels — the efficient sound and sight checks you get with Reliance Devices. These sentinels help you to save every minute of valuable production time—help prevent plant shut-downs and expensive accidents. • Reliance Boiler Alarms act instantly to warn of water levels dangerously low or high — safeguard lives and equipment. EYE-HYE saves time and steps, modernizes gage reading by bringing it down to instrument panel convenience. • Since 1884 the aggressive Reliance engineering policy has kept pace with modern trends in materials, steam pressures and temperatures — has maintained Reliance leadership in Boiler Safety Device manufacture. • The busier you are these strenuous days the more it pays you to keep power flowing, and protect your reputation for efficient low-cost power plant operation. Write today for full information. . . . THE RELIANCE GAUGE COLUMN COMPANY . . . 5902 CARNEGIE AVE. . . CLEVELAND, OHIO

TRADE MARK REG. IN U. S. PAT. OFF.

Reliance

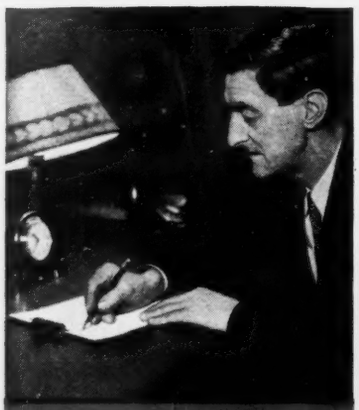
BOILER SAFETY DEVICES

REPRESENTATIVES IN PRINCIPAL CITIES TO SERVE YOU

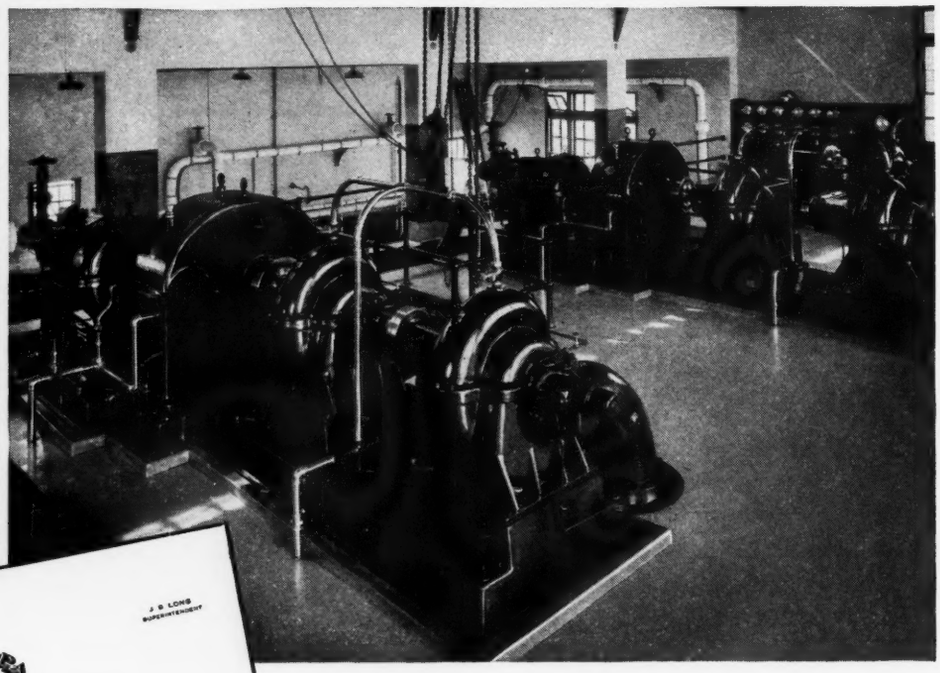


A Tip from TAMPA

after 9 Years of "Exceptionally Good Results"



CHIEF WM. B. STUART of Tampa's Water Department pumping station. His hobbies are clock-making and sweet-running turbines. For the latter he specifies *Texaco Regal Oil C.*



THREE DE LAVAL Steam Turbine pumping units in Tampa (Fla.) Water Works. Formerly, the lubricant replaced every 4 years, but now increased to 8 years since changing to *TEXACO REGAL OIL C.*

J. S. LONG
SUPERINTENDENT

ACCOUNTING DEPARTMENT

CITY OF TAMPA
WATER DEPARTMENT

Tampa, Florida, April 3, 1940

The Texas Company,
Atlanta, Georgia.

Gentlemen:

On the ninth anniversary of my change to Texaco Regal Oil "C" in the De Laval Steam Turbine pumping units in the City of Tampa Water Works plant, I felt you would be interested in knowing of the good results I have experienced with your products.

The first supply of Regal Oil "C" was in use continuously for eight years without trouble of any kind. When the time arrived to renew the oil I felt no hesitancy in placing Regal Oil "C" in the system again.

Due to the hard service required of oil in the high speed Turbines and reduction gear sets, I considered it had given exceptionally good results. I would not hesitate to recommend this product to anyone for similar use.

Taking this opportunity of thanking you for the engineering service rendered as well as the cooperation of your laboratory, I am,

Yours very truly,
Wm B. Stuart
Chief Engineer

WBS/s

YOU, TOO, can get similar results in your turbines. Trained lubrication engineers will gladly cooperate in making savings with *Texaco Regal Oils.* Phone the nearest of more than 2300 Texaco warehousing points in the 48 States, or write:

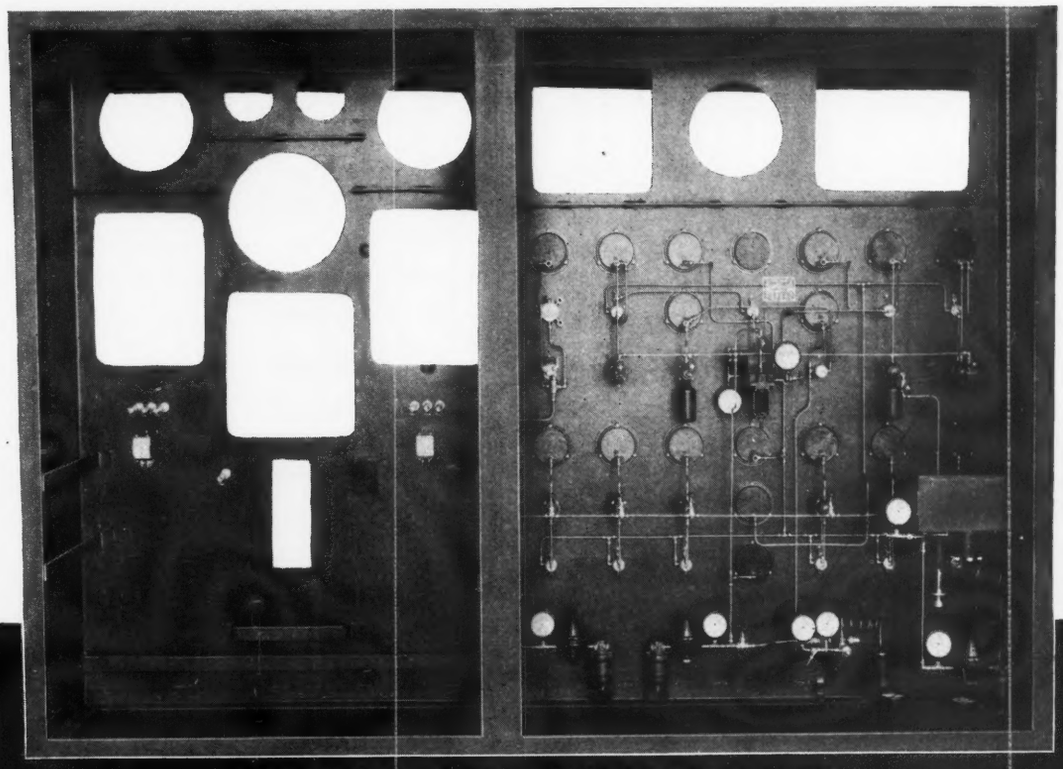
The Texas Company, 135 E. 42nd St., N. Y., N. Y.

TEXACO
Regal
Oils
TEXACO REG. T.M.
FOR TURBINE LUBRICATION

TEXACO DEALERS INVITE YOU TO ENJOY

FRED ALLEN in a full-hour program every Wednesday night. CBS, 9:00 E.S.T., 8:00 C.S.T., 10:00 M.S.T., 9:00 P.S.T.

METROPOLITAN OPERA every Saturday afternoon, NBC. See local newspaper for time and station.



Rear view of a Hagan control panel before instruments are mounted.

Look "under the hood" when you buy *Combustion Control*

With Hagan it's Engineering that Counts!

YOU don't trade in a combustion control system every year or two, so look "under the hood" when you do buy one. Hagan control panels grace the boiler rooms of leading power plants everywhere, but it is the engineering craftsmanship behind those panels which maintains the Hagan reputation for consistent, reliable performance under severest operating conditions.

Hagan Control is precisely engineered from master sender to the tiniest link in the system. Many original Hagan installations, now more than 20 years old, are still operating efficiently. The same basic principles on which they were constructed are utilized in the newest, most advanced Hagan systems —proof of the engineering soundness that characterizes all Hagan equipment.

When you buy a combustion control system, therefore, look "under the hood." Investigate the workmanship *behind* the panel board, the operation and construction of the equipment to be used and buy the system you can rely upon, not for a year or two, but for a decade or more. Yes, look "under the hood" and then buy Hagan!

HAGAN CORPORATION · 300 ROSS STREET · PITTSBURGH, PA.

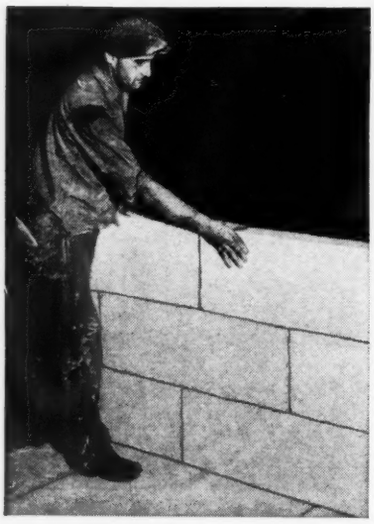
HAGAN *Automatic* COMBUSTION CONTROL

The pioneer . . . and still the leader

3-WAY COMBINATION FOR

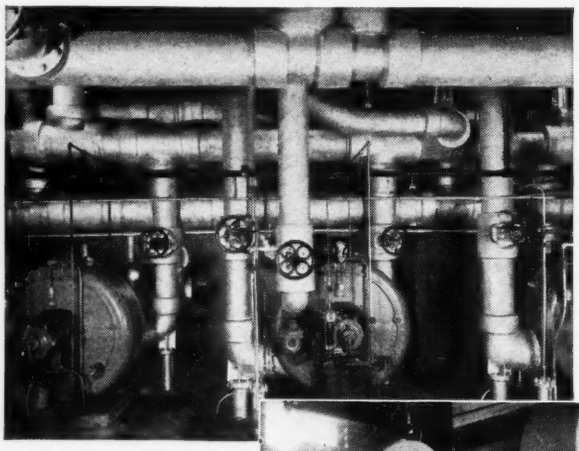
Durable and unusually efficient, these J-M Power Products last longer with less maintenance . . . give improved performance wherever used . . .

1 J-M INSULATIONS



ON BOILERS . . .

Where insulation is required to resist temperatures between 600° and 1900°, J-M Superex Blocks are ideal. Even under severe operating conditions, this durable material gives long, efficient service . . . offers maximum protection against costly heat losses. Use L-W Superex up to 1500° F.; H-T Superex between 1500° and 1900° F.

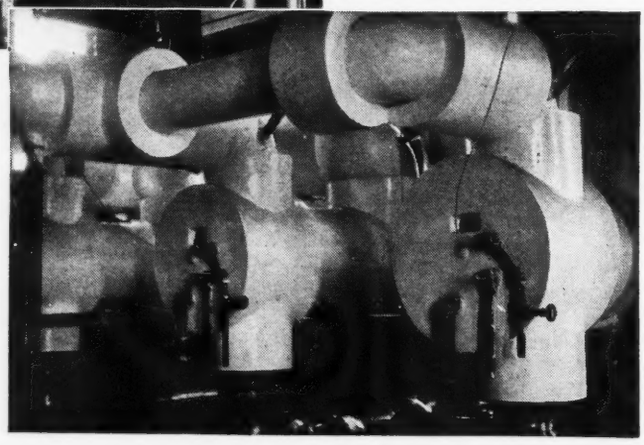


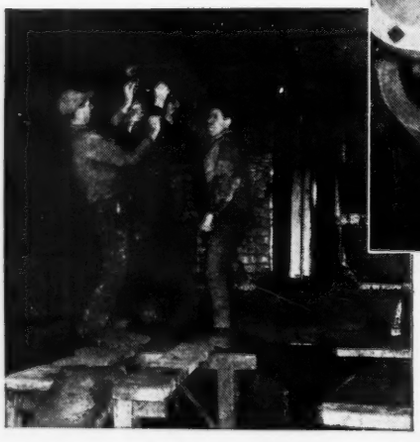
ON SUPERHEATED STEAM LINES . . .

The new Johns-Manville L-W Superex provides an effective safeguard against excessive heat waste. Recently developed by the J-M Laboratories to meet the need for a more efficient high-temperature pipe insulation, it offers exceptional heat resistance and unusually high insulating value.

FOR LINES UNDER 600°

. . . You save money by using J-M 85% Magnesia Pipe Insulation. For many years the standard insulation for steam lines, it combines light weight with high insulating efficiency.





FOR LOW TEMPERATURES

. . . J-M Rock Cork has been giving low-maintenance service for more than thirty years. Supplied in both sheet and pipe-covering form, it is basically mineral . . . does not burn, rot or decay. Unusual moisture-resistance assures permanently high insulating efficiency.

JM JOHNS-MANVILLE

LOWER POWER-PLANT COSTS

2 J-M PACKINGS AND GASKETS

AGAINST STEAM, AIR, BRINE, OIL . . .

J-M Sea Rings are ideal for rods and plungers. Entirely automatic, they seal on work stroke, release on return . . . minimize rod wear.

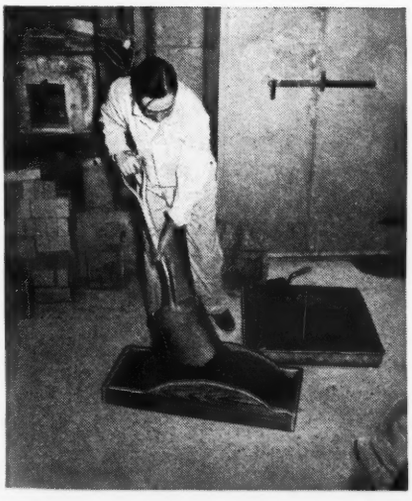
ON FLANGES . . .

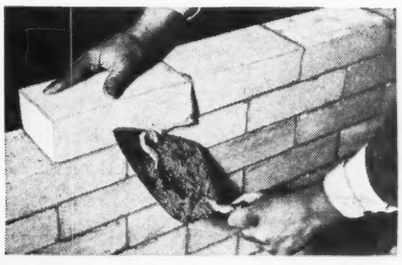
and other parallel surfaces, it will pay you to use J-M Service Sheet. It is dense, yet resilient . . . always uniform in quality. Stocks may be carried indefinitely, for it does not deteriorate with age.

FOR BOILER HANDHOLES AND MANHOLES . . .

J-M Kearsarge Gaskets form perfect seals every time. Made of specially treated Asbesto-metallic cloth, they assure long life, low maintenance.

3 J-M REFRACTORY PRODUCTS





FOR BONDING . . .

You get strong, tight joints with these J-M Refractory Cements: Hellite, air-setting—for bond or cushion joints; No. 31, heat-setting—for bond or cushion joints; No. 32, heat-setting—for brick-to-brick joints. Hellite and No. 32 also used for washcoating.

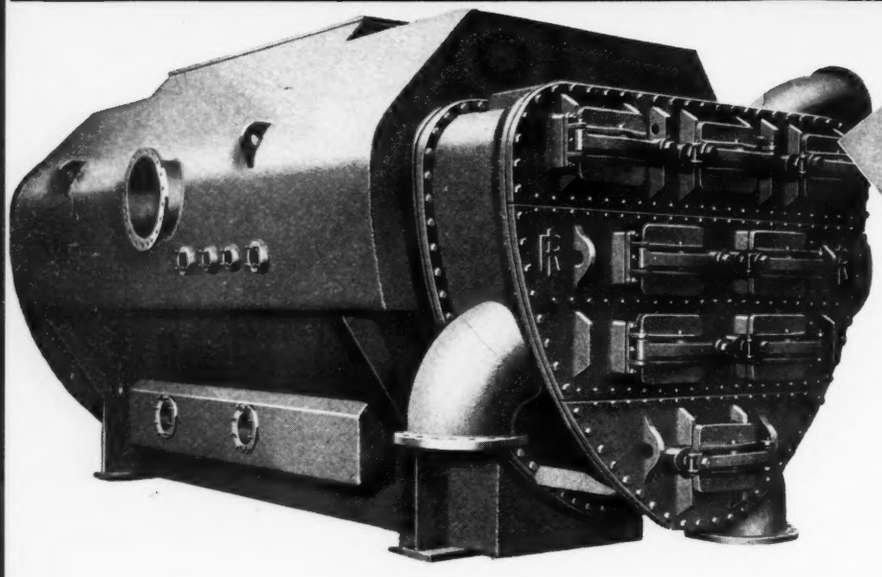
FOR SPECIAL SHAPES . . .

Cast your own shapes with J-M Firecrete. Air-sets, handles like concrete, forms any shape. Also ideal for poured door linings. 3 types: Standard (2400°), High Temp. (2800°), Light Weight (2200°).

POWER PRODUCTS

These well-known J-M materials are saving money for thousands of plants all over the country. The materials shown on these pages represent only a small part of the complete J-M line of Power Products. You should have full details on them all. Write for catalog GI-6A. Address Johns-Manville, 22 E. 40th St., New York, N. Y.

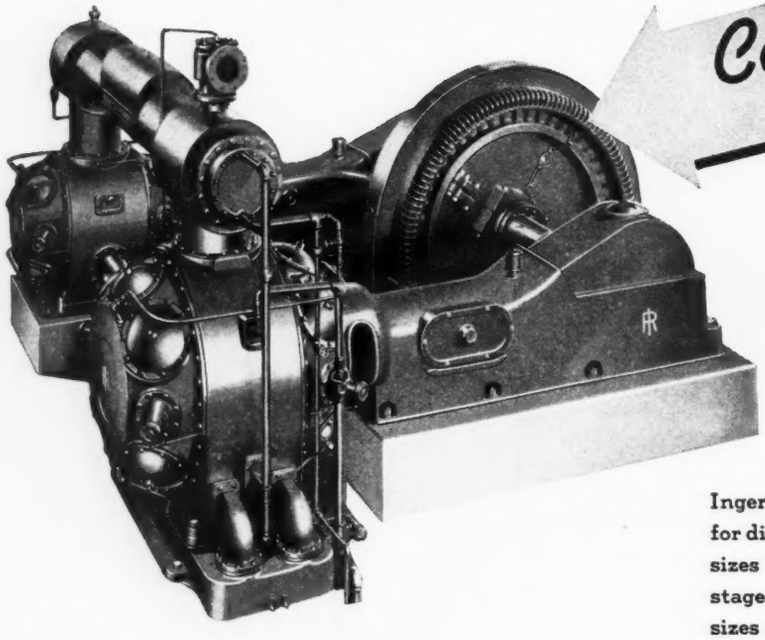
Buy I-R EQUIPMENT for Economy and



Condensers

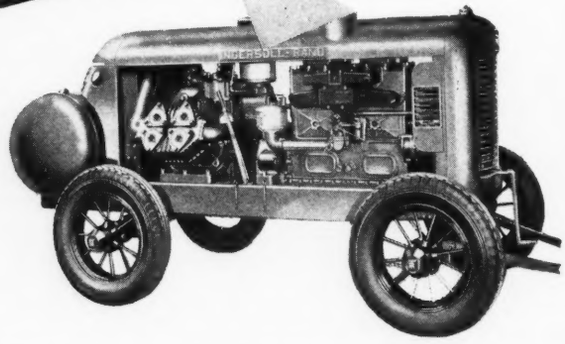
Surface and Barometric types

I-R high efficiency surface and barometric condensers are the acknowledged standard of the power industry. Sizes up to 160,000 kw. Ingersoll-Rand also builds single and multi-stage steam jet ejectors.



Compressors

Sizes 1/4 to 3000 hp

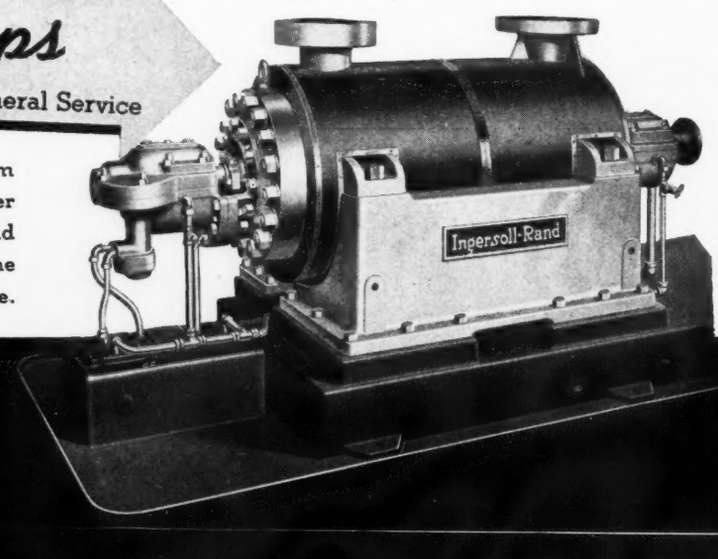


Ingersoll-Rand compressors are available in all sizes and types for direct-connected or belted motor drive. There are also many sizes with built-in steam, Diesel, or gas power cylinders. Two-stage air-cooled portable units are available in all standard sizes and mountings with either gasoline or oil engine drive.

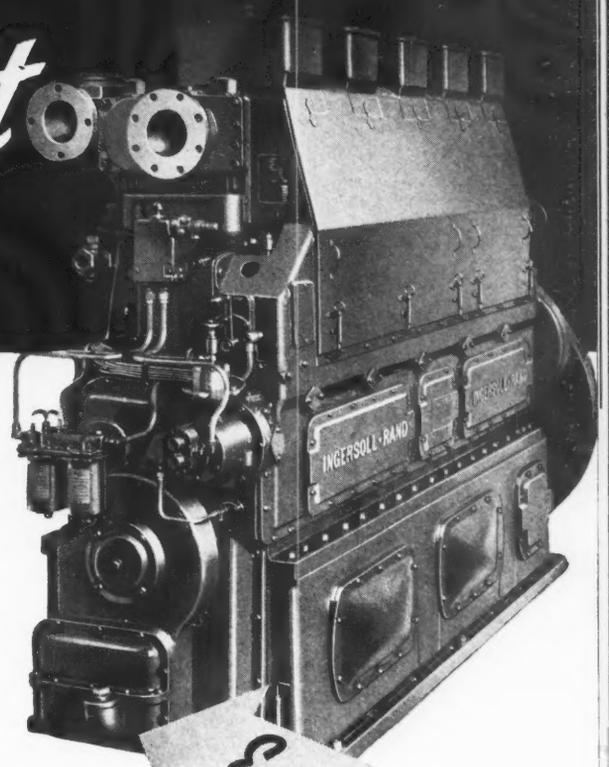
Pumps

Boiler Feed and General Service

Multi-stage boiler-feed pump capacities range from 20 to 3000 gpm and pressures up to 3000 lbs. Other special purpose pumps are available for hot-well and circulating service. The Motorpump is one of the many I-R general service pumps for power plant use.



d Efficiency in your Power Plant!



Engines
Diesel and Gas

EACH I-R unit is the result of careful research and long manufacturing experience—into each is built those features which protect the reliability of your operating setup and add to its economy and efficiency.

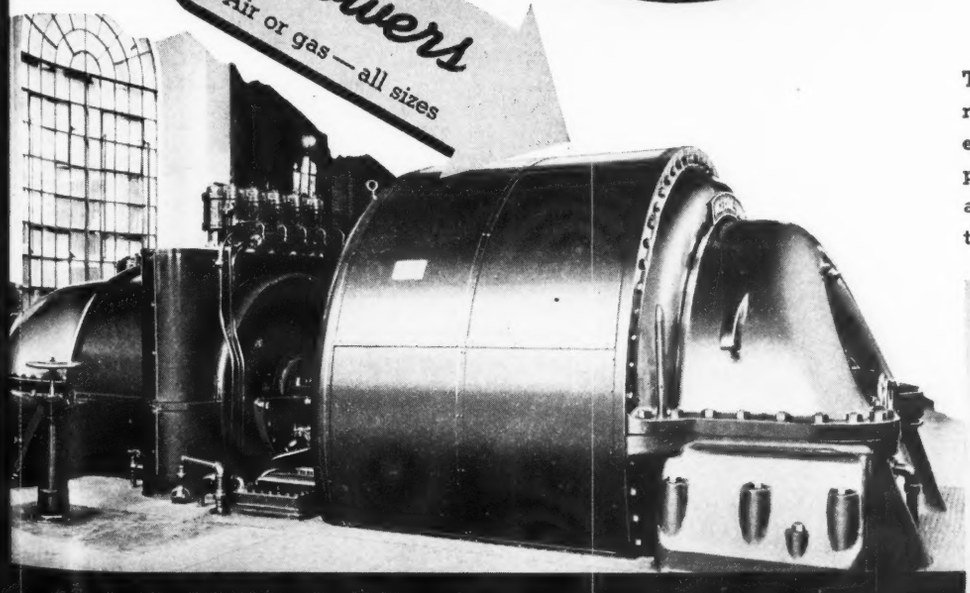
In selecting I-R equipment, you have the satisfaction of buying from power plant specialists. Your choice will be made from a complete line of up-to-the-minute products—each of which has established its claim to leadership. The local I-R representative has the full facts, and his knowledge and experience will help you in selecting the correct units for your installation.

Type S Vertical Diesel, 3 to 8 cylinders, 190 to 510 bhp at 600 rpm; Type SG Convertable Gas-oil Engine, 190 to 510 bhp; Gas Engines, 185 to 650 bhp. All are built and rated for continuous full-load service.

I-R turbo blowers are made in sizes from 3 to 12,000 hp, for handling air or gas at all industrial pressures and in volumes up to 100,000 cfm.

Impact Wrenches
And other pneumatic tools

Blowers
Air or gas—all sizes



The I-R Impact Wrench has no equal for removing or applying nuts, staybolt caps, studs, etc. Other I-R pneumatic tools include complete lines of hoists, drills, grinders, chipping and riveting hammers, as well as all sizes and types of rock drills and paving breakers.

Birmingham	Detroit	Philadelphia
Boston	Duluth	Pittsburgh
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	Havana	

834-14

Ingersoll-Rand

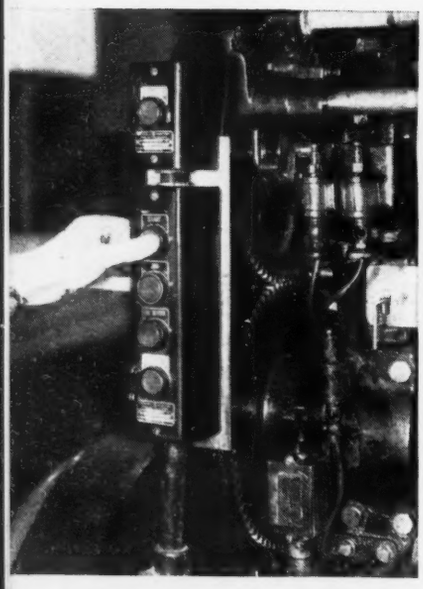
11 BROADWAY, NEW YORK CITY

5 WAYS TO IRON OUT

CENTRALIZED CONTROL FOR CONTINUOUS OPERATION

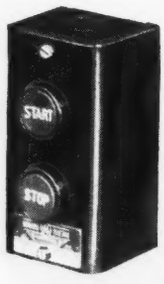
Here's control that's the "brains" of a mid-west coal-washing tipple. If any one drive should shut down, stopping a conveyor, shaker, or pump, all drives supplying coal to this point will be shut down automatically to prevent a costly "pile-up." *G-E combination starters* do the job by special interlocking. Centrally located, they make it possible to quickly return the plant to operation when the trouble is cleared. User claims they're safer and cost less to install than separate devices.

1 **G-E combination starters have motor circuit switch and fuses (or circuit breaker) plus magnetic starter with overload protection, all in a single safety-interlocked enclosure.**



ANOTHER PUSH BUTTON MAY SAVE DOZENS OF STEPS

No waste motion for this printing-press operator as he jogs the roll. A conveniently located push-button station eliminates lost motion in set-up operations—frees the press for extra hours of running time each day. This is an example of the many ways that a simple control device, properly applied, can make possible substantial savings over a period of years. Perhaps you, too, have motor-driven equipment that would be more efficient if controlled from more than one point.



2 **New inexpensive standard-duty push-button stations are easy to install—may save many times their cost.**

INCREASED PRODUCTION REQUIRES THE EFFICIENCY AND SAFETY OFFERED BY MODERN AUTOMATIC CONTROL

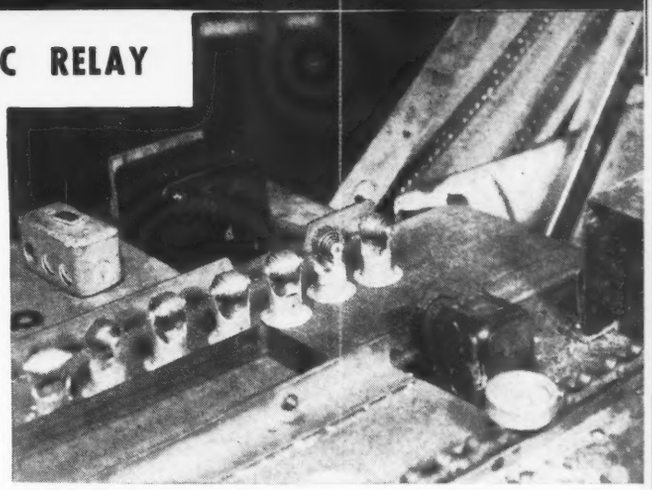
PRODUCTION KINKS

KNOW YOUR OUTPUT—PUT IN A PHOTOELECTRIC RELAY

3

Inexpensive photoelectric relay suitable for counting, limiting, sorting, and similar work.

A progressive valve manufacturer put a *photoelectric relay* on each of the many assembly tables to record output by means of a magnetic counter. Perhaps such a control could help you keep track of production. The counter can be located in your office.

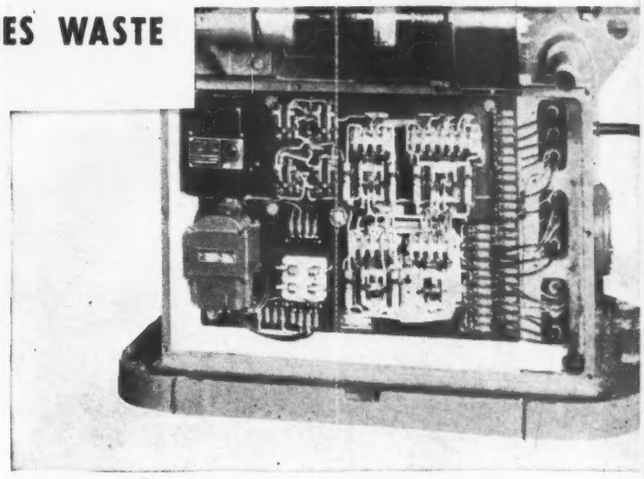


AUTOMATIC PROCESS TIMING BOOSTS OUTPUT—SAVES WASTE

4

Timers and time switches, available for process jobs, weld timing, and other purposes, save time and money.

A Chicago valve manufacturer until recently "ground in" valve stems and seats by having each machine operator "time" the 30-second operation from a clock. Installing automatic timing made clock watching unnecessary—produced a more accurate product, and allowed the operator to perform other operations during the 30-second interval.

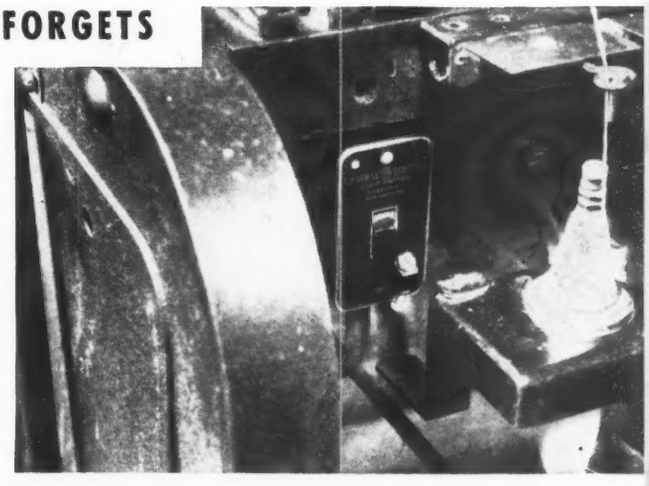


INSTALL A LIMIT SWITCH—IT NEVER FORGETS

5

G-E lever-and-gear-type limit switches are available for every type of application.

Wasting material by under- or over-filling the bobbins is impossible on this textile spinning frame. When bobbins are filled just right, the rail trips the limit switch, shutting off the machine until the operator can change bobbins. Perhaps this is a tip that can save you material and time.



GENERAL ELECTRIC COMPANY, SCHENECTADY, N. Y.

GENERAL ELECTRIC

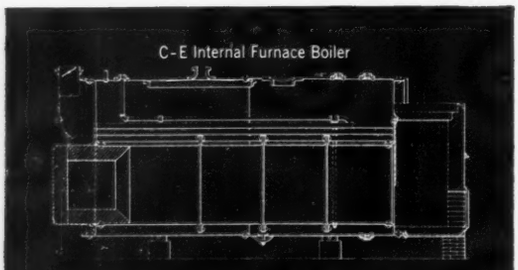
670-22

COMBUSTION ENGINEERING
COMPANY, INC.

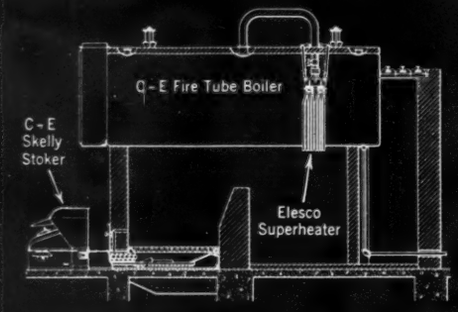
200 MADISON AVENUE, NEW YORK, N. Y.

Canada: Combustion Engineering Corporation, Ltd., Montreal

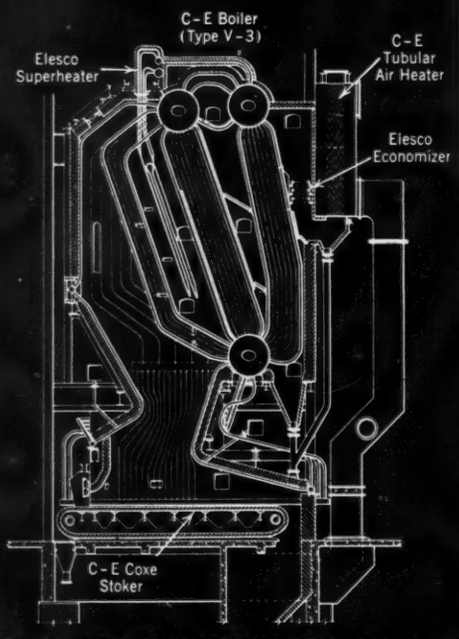
Briefly presented here is the most extensive line of boiler, fuel-burning and related equipment offered by any manufacturer. It meets every capacity requirement from 1,000 to 1,000,000 lb of steam per hr. Detailed information is contained in separate bulletins which are available on request.



One of eleven duplicate gas-fired units installed in a Refinery. Capacity—6000 lb per hr. Design Press.—150 lb.



A small unit installed in a Textile Plant. Capacity—6500 lb per hr. Design Press.—150 lb.



One of two units installed in a Public Utility Plant. Designed to produce 80,000 lb of steam per hour at 425 lb pressure and 775 F temperature.

BOILERS

C-E Sectional Header Boiler—Built in sizes to suit the requirements of commercial practice. The sinuous headers are forged from seamless steel tubes. The ends of the headers are closed by a patented construction which assures strength and tightness. The hand-holes have machined inside faces. Fusion welded drums.

C-E Heine Box Header Boiler—Built in cross-drum and longitudinal-drum types ranging in size from 1000 to 12,000 sq ft of heating surface, and for pressures up to about 300 lb per sq in. Especially suited for limited space conditions and low headroom.

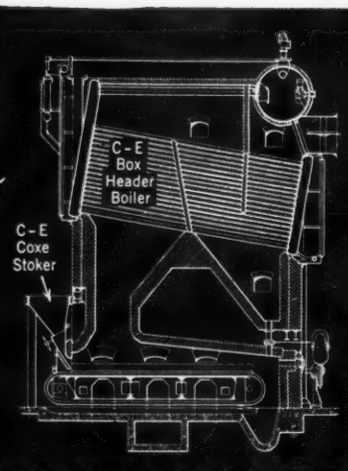
C-E Bent Tube Boilers—The most complete line of bent tube boilers offered by any manufacturer. Includes two, three, four and multi-drum types, which collectively range in size from about 900 sq ft of heating surface up to the largest ever built. Available for any desired pressure and adaptable to the installation of superheater surface for any practical steam temperature requirements. The standard lines include 3-drum types of both low head room and conventional designs, and a 4-drum group incorporating unique design features which mark it as outstanding in its class. Standard 2-drum boilers in sizes below and in the lower range of the Type VU Steam Generator are designed principally for stoker or oil firing. Many of the most notable modern boiler installations are C-E Units. Eight of the ten steam generating units in the world capable of producing a million or more pounds of steam per hour are C-E Units.

C-E Fire Tube Boilers—A complete line of standard fire tube boilers of various types, including stationary, semi-portable and waste heat designs. Also the C-E Nuway Boiler, an hrt type which features an effective circulation control attained by interior baffling.

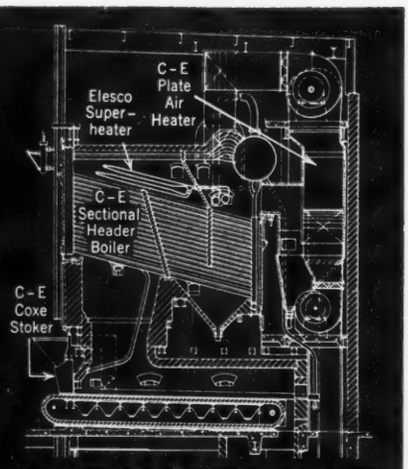
C-E Waste Heat Boilers—Built in various straight tube and bent tube designs. Water tube and fire tube types. Also forced circulation types for recovery of heat from exhaust gases of internal combustion engines.

SUPERHEATERS

Elesco Superheaters—For every superheat application, including integral designs for stationary boilers of all kinds, separately fired types for process work and similar purposes, and girth types especially suited for hrt boilers.



One of two duplicate units installed in a Chemical Plant. Capacity—30,000 lb per hr. Oper. Press.—200 lb.



One of two similar units installed for a University. Capacity—75,000 lb per hr. Design Press.—250 lb. Steam Temp.—508 F.

COMPLETE STEAM GENERATING UNITS

C-E Steam Generator (Type VU)—A complete unit embodying all the elements required for efficient steam generation in a simple compact arrangement. Built for capacities from 30,000 lb per hr up to approximately 300,000 lb. Applicable to both industrial and utility plants.

Complete C-E Units—Comprising any combination of boiler, furnace, firing equipment and auxiliaries in coordinated overall designs exactly suited to specified conditions.

C-E WATER-COOLED FURNACES

Extended surface, plain tube and Elesco bifurcated types are available. Tubes may be cleaned in the same manner as boiler tubes. Exposed surfaces give maximum heat absorption. Insulating materials and casings are supported or suspended independently of tubes. In stoker-fired installations, those portions of the lower wall surfaces which are subjected to direct contact with the fuel or ash may be covered with heavy gage finned tubes.

PULVERIZED FUEL EQUIPMENT

C-E Pulverized Fuel Systems are available in either direct-fired or storage types, in sizes ranging from those suitable for the smallest boilers for which the application of pulverized fuel is practicable up to the largest. The *C-E Raymond Bowl Mill* is applicable to either system. It employs an improved adaptation of the roller principle, which results in an efficient, quiet, reliable pulverizer having a wide range of capacity with uniform fineness of product. The *C-E Raymond Impact Mill* is used only with the direct-fired system. It is a high speed mill of simple, rugged design and is especially suitable for smaller installations. *C-E Burners* are available in various designs for firing vertically, horizontally or tangentially. Horizontal and tangential burners may be fitted to burn oil, gas or coal, alone or in combination.

STOKERS

The C-E stoker line is the most complete offered by any manufacturer. It comprises virtually all types in general use today, such as single and multiple retort underfeed, traveling grates of both chain and bar types and the spreader type stoker. . . . Among the underfeeds are the *C-E Skelly*, the *Type E* and the *Low Ram* which are widely known, nearly 5000 having been installed in the U.S.A. alone. These types are collectively suitable for boilers ranging from about 20 rated hp up to the largest. The traveling grates include those known by the trade names *Coxe* and *Green* and are applicable for boilers from about 150 rated hp up. The C-E Spreader Stoker is suitable for boilers from about 100 rated hp up. There is a C-E stoker or stokers for every solid fuel suitable for stoker use—anthracite, bituminous, coke breeze and lignite.

HEAT RECOVERY EQUIPMENT

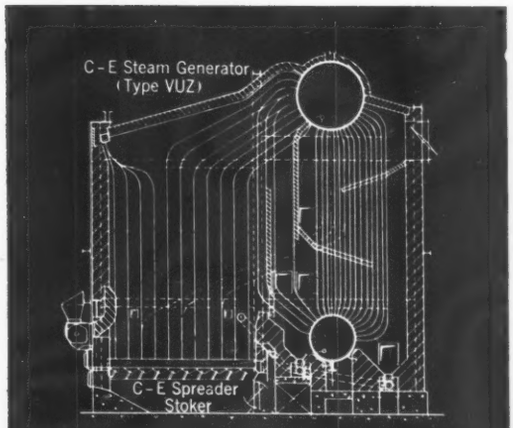
Elesco Economizers—Extended surface and plain tube types built in both the continuous loop and accessible designs. The use of bifurcated tube design reduces the number of joints on the latter type by half.

Air Heaters—Both C-E plate and tube types are available.

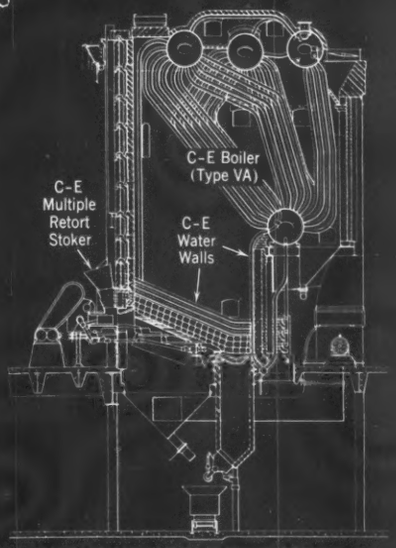
FABRICATED PRODUCTS

C-E shop facilities, unexcelled by any in the country, are entirely adequate for the fabrication of all kinds of pressure and vacuum vessels, welded or riveted, in carbon, alloy or clad steels; also prepared to handle all classes of tank and plate work.

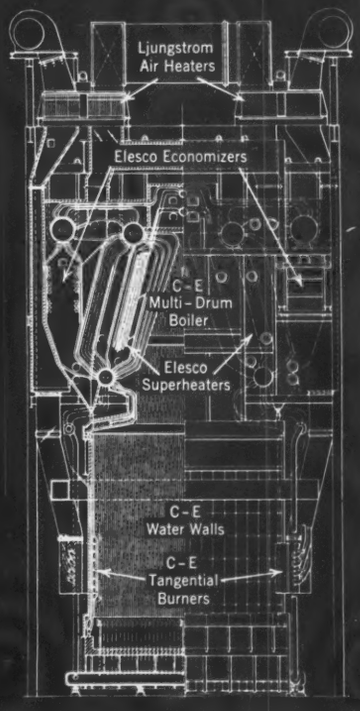
A-568



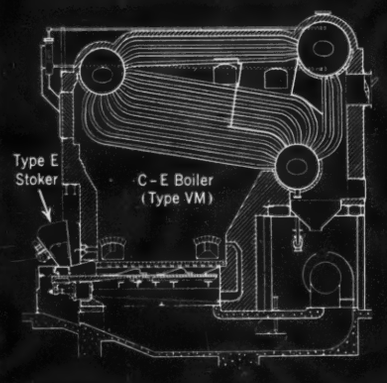
This unit installed for a Distilling Company. Capacity—30,000 lb per hr. Design Press.—400 lb.



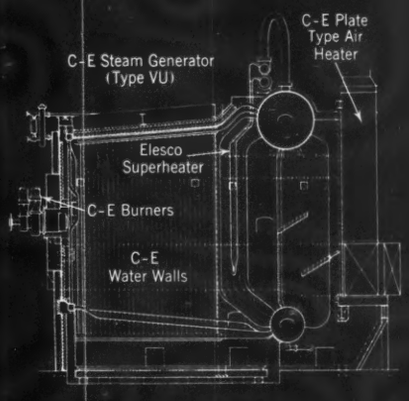
One of three duplicate units for an Automobile Plant. Capacity—45,000 lb per hr. Design Press.—225 lb.



A large unit superposed on existing equipment in a Public Utility Plant. Capacity—1,000,000 lb per hr. Design Press.—1425 lb. Steam Temp.—925 F.



This unit installed for a Tobacco Company. Capacity—23,000 lb per hr. Design Press.—275 lb.



A standard VU Unit installed for a University. Capacity—75,000 lb per hr. Design Press.—225 lb. Steam Temp.—437 F.

"PHILLIE GEAR WANTS TO TALK TO YOU ABOUT THIS WORM REDUCER DESIGN..."
"—WELL, HIS SUGGESTIONS USUALLY CHANGE A PROSPECT INTO A CUSTOMER."

Philadelphia LIMITORQUE CONTROL operates all types of valves, etc., safely, economically, from convenient stations.
Philadelphia WORM GEAR SPEED REDUCER right angle drives—vertical or horizontal. Wide range of ratios and horsepowers.
Philadelphia HERRINGBONE SPEED REDUCER for heavy loads at high speed. Single, Double, Triple Reductions, various ratios and horsepowers.
Philadelphia MOTOREDUCER The economical self-contained drive. Horizontal or Vertical types—various ratios and horsepowers.
Philadelphia GEARS All types and sizes of industrial gears. Can be supplied in all materials.

To men versed in speed reducer applications, the inherent benefits in the Philadelphia Worm Gear Reducer design become apparent almost immediately.

To men versed in speed reducer operation, the superiority becomes evident the moment power is applied. The smooth operation tells them of the precision cut worm and gear mounted for exact accuracy.

To men versed in the maintenance of speed reducers, the wisdom of choosing Philadelphia becomes obvious from its trouble-free service. Anti-friction bearings . . . sturdy, cast iron housings . . . adequate lubrication tell the story.

Latest Worm Gear Reducer catalog awaits your request. It shows construction details, dimensions and engineering facts.

PHILADELPHIA GEAR WORKS

Industrial Gears and Speed Reducers
Erie Ave. and G St.
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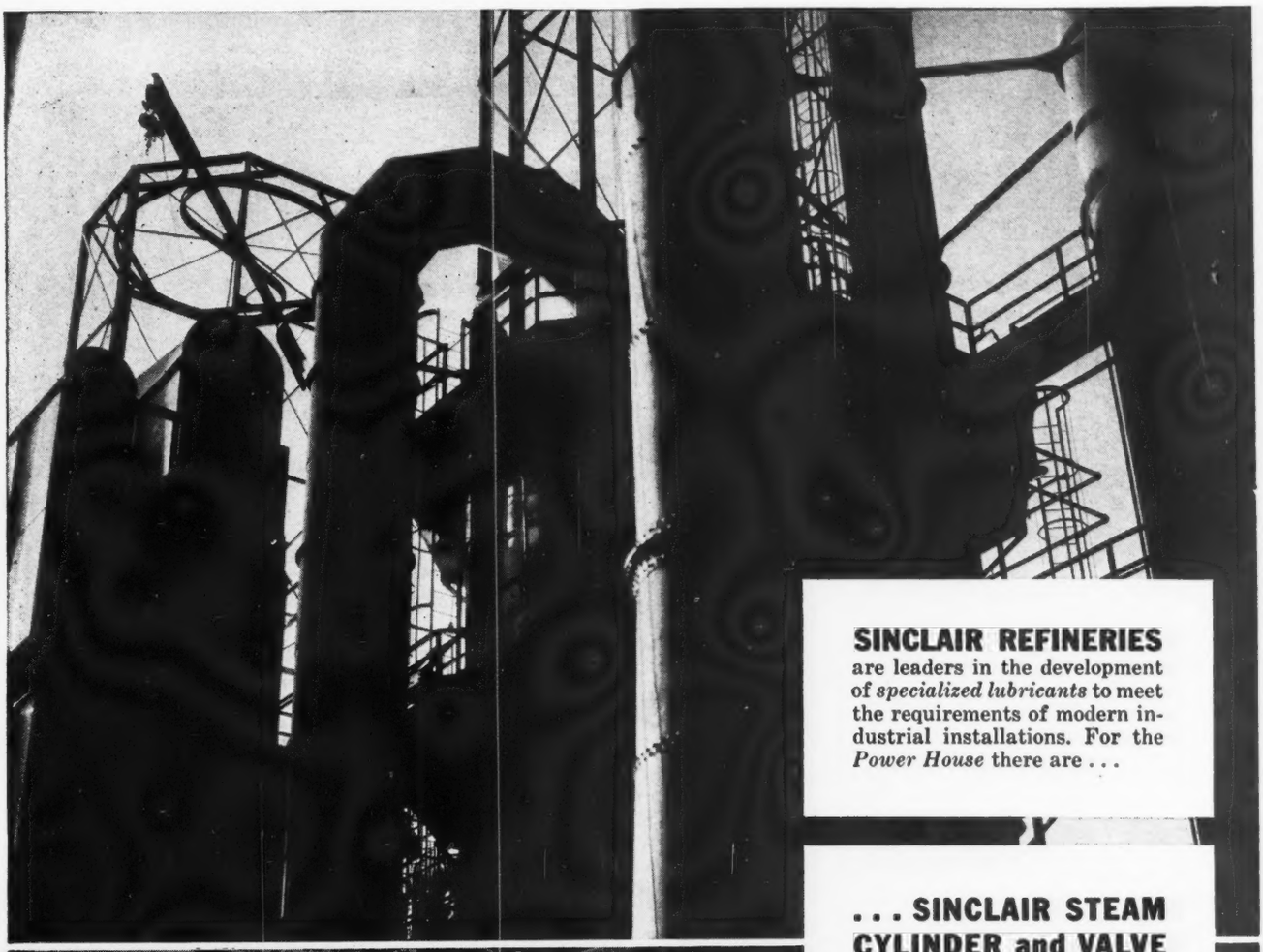
New York • Pittsburgh • Chicago



SINCLAIR REFINERIES are leaders in the development of *specialized lubricants* to meet the requirements of modern industrial installations. For the *Power House* there are . . .

. . . SINCLAIR STEAM CYLINDER and VALVE OILS suited to the particular pressure, temperature and moisture conditions individual to your engines. Economy of operation and maintenance depend upon the correct oil. Sinclair has it. Sinclair engineers will gladly confer with you about the use of correct power house oils for your plant. Write the nearest Sinclair office or Sinclair Refining Company, 630 Fifth Avenue, New York, N. Y.

* * *

(left) **EQUIPMENT IN CITY WATER WORKS, OWOSSO, MICHIGAN.** *Steam Cylinders of this engine have been lubricated for past 6 years with Sinclair Superheat Valve Oil.*

Write for "The Service Factor", a free publication devoted to solution of lubrication problems.

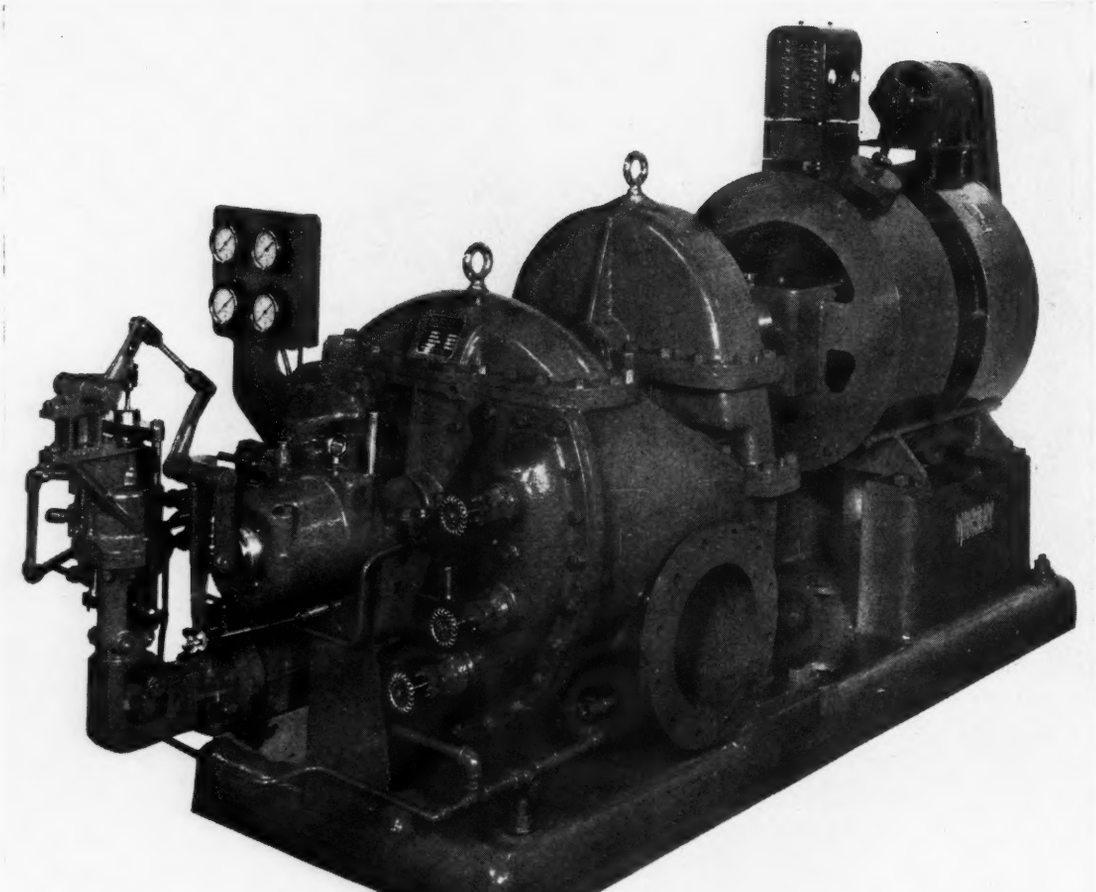
SINCLAIR INDUSTRIAL OILS

SINCLAIR REFINING COMPANY (Inc.)

2540 W. CERMAK RD. CHICAGO • 10 W. 51ST ST. NEW YORK • 1907 GRAND AVE. KANSAS CITY • 573 W. PEACHTREE ST. ATLANTA • FAIR BUILDING, FT. WORTH

MURRAY

"Packaged" Turbine Generator Units



Murray "Packaged" Turbine Generating Units are the answer to the problem of moderate electric generating loads demanding economical solution.

These rugged, dependable Murray "Packaged" Turbine Generating Units—

—supply economical electric power
—fit into limited space
—have the generator control at the generator
—eliminate the need for switchboard

The above photograph showing a 100 kw Unit built for an institution is a typical example.

There is a size and type available to meet your requirements.

Have our district representative or home office show you how these Murray "Packaged" Generating Units will save you money.

MURRAY IRON WORKS COMPANY

BURLINGTON, IOWA

Spray-Spred FIRING METHOD
EXCLUSIVE WITH Fyr-Feeder
IS REVOLUTIONIZING COAL BURNING . .

NOW A TWO UNIT Fyr-Feeder

MODEL R 4072
200 D. H. P. CAPACITY

Only $995
F. O. B. FACTORY
CONTROLS EXTRA

OTHER SIZES IN PROPORTION

Sets a new high in Cost Savings

The Multiple FYR-FEEDER Stoker has changed complicated boiler firing to *simplicity itself.* Exclusive, proved, efficient features—few working parts, all slow-moving—most effective, dependable design—new economy that materially cuts former coal burning costs.

Here's how each FYR-FEEDER unit works.—The coal is drawn mechanically from a large hopper to inclines inside the furnace. The coal then rolls down these inclines into air streams under light pressure. Thus, coal is "air-cleaned" and coal dust is "sprayed" and instantly burned in suspension by the air which sprays it. The balance of the coal is spread along the length of the forced draft grate according to weight-size of each piece.

Fire cleaning is easy and takes only a few minutes. FYR-FEEDER Stokers are always built with *two* or *more* individually-controlled FYR-FEEDER Spray-Spred units so that coal feeding on one side of the grate can be stopped, permitting the coal on that side to burn out completely before cleaning or dumping the ashes from that side of the grate. While cleaning fires on one side, *the feeders on the other side are* SPRAY-SPREDing coal to maintain steam pressure.

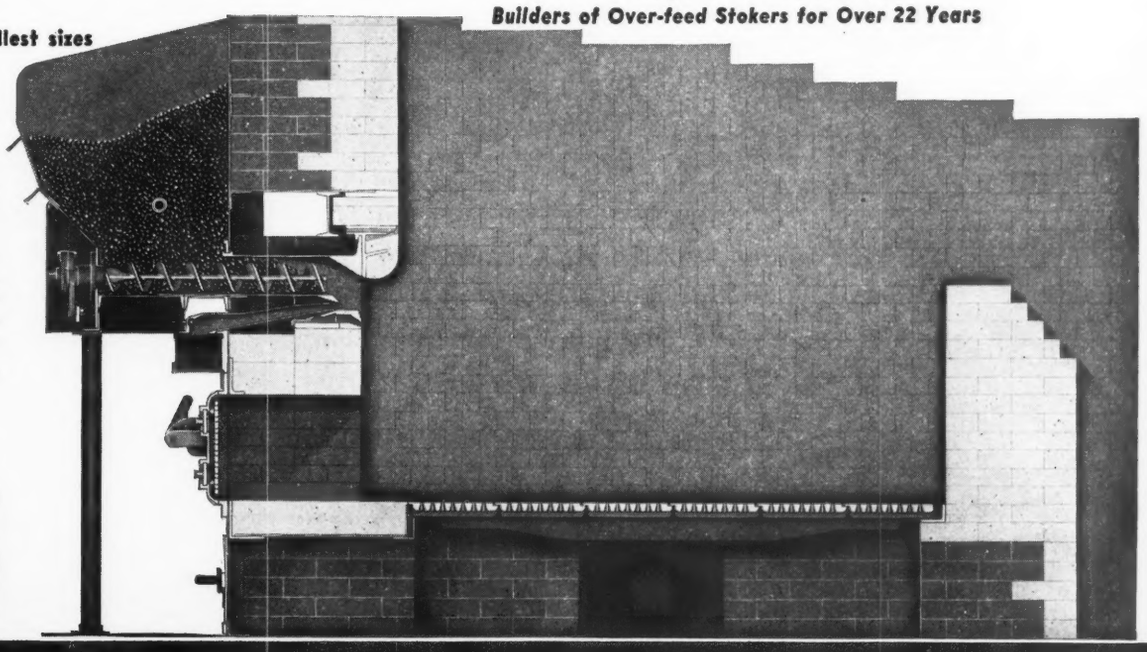
Spray-Spred capacity of each unit varies according to size and speed and will deliver and Spray-Spred coal up to as much as 500 developed horsepower per unit. Thus, 10 FYR-FEEDER units can be supplied to handle a 5000 horsepower load. Grates may be Stationary, Dumping or Chain Grates (where continuous ash removal is wanted). FYR-FEEDERS may be set directly over fire doors or as much as 10 feet or more above grates.

Learn what the Multiple FYR-FEEDER'S *simplicity and most natural way of firing coal* will do for you. Many hundreds of these FYR-FEEDER Spray-Spred units are proving daily that the best and simplest way to fire any boiler efficiently is to fire coal by SPRAY-SPREDing it over a forced draft fire on a grate.

AMERICAN COAL BURNER COMPANY
155 E. Superior St., Chicago, Ill.
Builders of Over-feed Stokers for Over 22 Years

yr-Feeder SIMPLICITY
gives you many benefits

- nstantaneous ignition of fines
- ir spray spreads the coal over grates
- ess power to operate
- ower maintenance costs
- educed steam costs
- urns lowest price coal and smallest sizes
- ires cleaned quicker
- anking losses reduced
- eadily adaptable to various ypes of boilers
- R-CLEANING all of the coal, in- e the furnace, insures a freer supply to the coal being burned the grates.
- the FYR-FEEDER furnace, two tinct combustion zones are main- ined—one for burning the larger ces of coal, and one for burn- the fines and dust in suspen- n, each with its own individual, parately-controlled air supply.



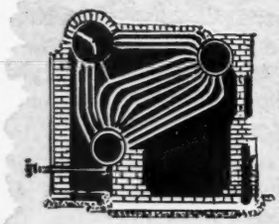
Get all the Facts WRITE TODAY

Spray-Spred MULTIPLE Fyr-Feeder

REDUCES COAL BILLS - - BURNS CHEAPEST COAL SIZES

6 VERY IMPRESSIVE FACTS

12,614,000 lb. per hr.



Steam Generated

690,000

K.W. per hr.
(High Pressure Units Only)
Capacity

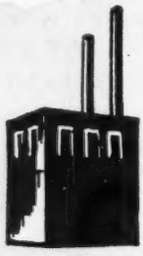
900°F. to 950°F.

Temperature Conditions

1240 to 2200 lb.

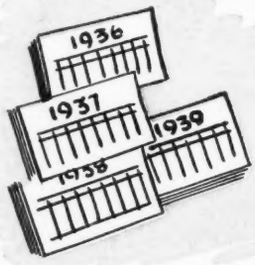
Pressure Range

13 CONTRACTS



Awarded

4 YEARS



1936 to 1940

The Figures given above show the confidence placed by consulting engineers, central station and industrial plant engineers and operators in this organization's ability to design, prefabricate and erect piping, regardless of the size of the job. The Kellogg Company has also prefabricated and erected many piping jobs ranging from 200 pounds pressure up.

Call in this organization the next time you have a piping project.

THE M. W. KELLOGG COMPANY · JERSEY CITY, NEW JERSEY · 225 BROADWAY, N. Y.

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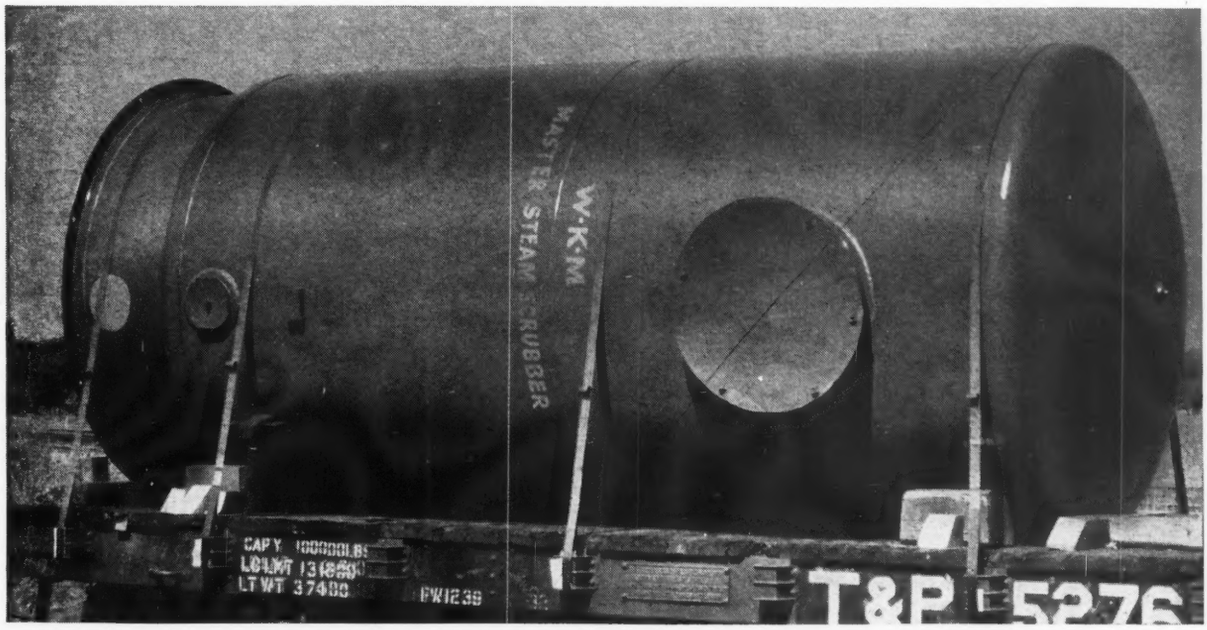
"Masterflex" Prefabricated Piping Systems · "Masterweld" pressure vessels for Power, Refinery and Chemical Industries. Heat Exchangers. Pyrolytic and Catalytic Cracking Units, Reforming, Dehydrogenation, Alkylation, Desulphurization. Thermal and Catalytic Polymerization Units · JUIK Processes for Lubricating Oil Plants. Plastic Refractories · Radial Brick Chimneys.

CLEANING EXHAUST STEAM*



A W-K-M MASTER SCRUBBER FOR CLEANING EXHAUST STEAM IN A 30" LINE IN A PLANT OF ONE OF THE LARGEST AUTOMOBILE MANUFACTURERS . . . ORDERED AS A RESULT OF THREE YEARS' EXPERIENCE WITH ONE IN A 20" LINE.

*They also clean air, gas and high pressure steam equally well in lines 1/8" to 60" in diameter, at vacuum to 3000 lbs. pressure.

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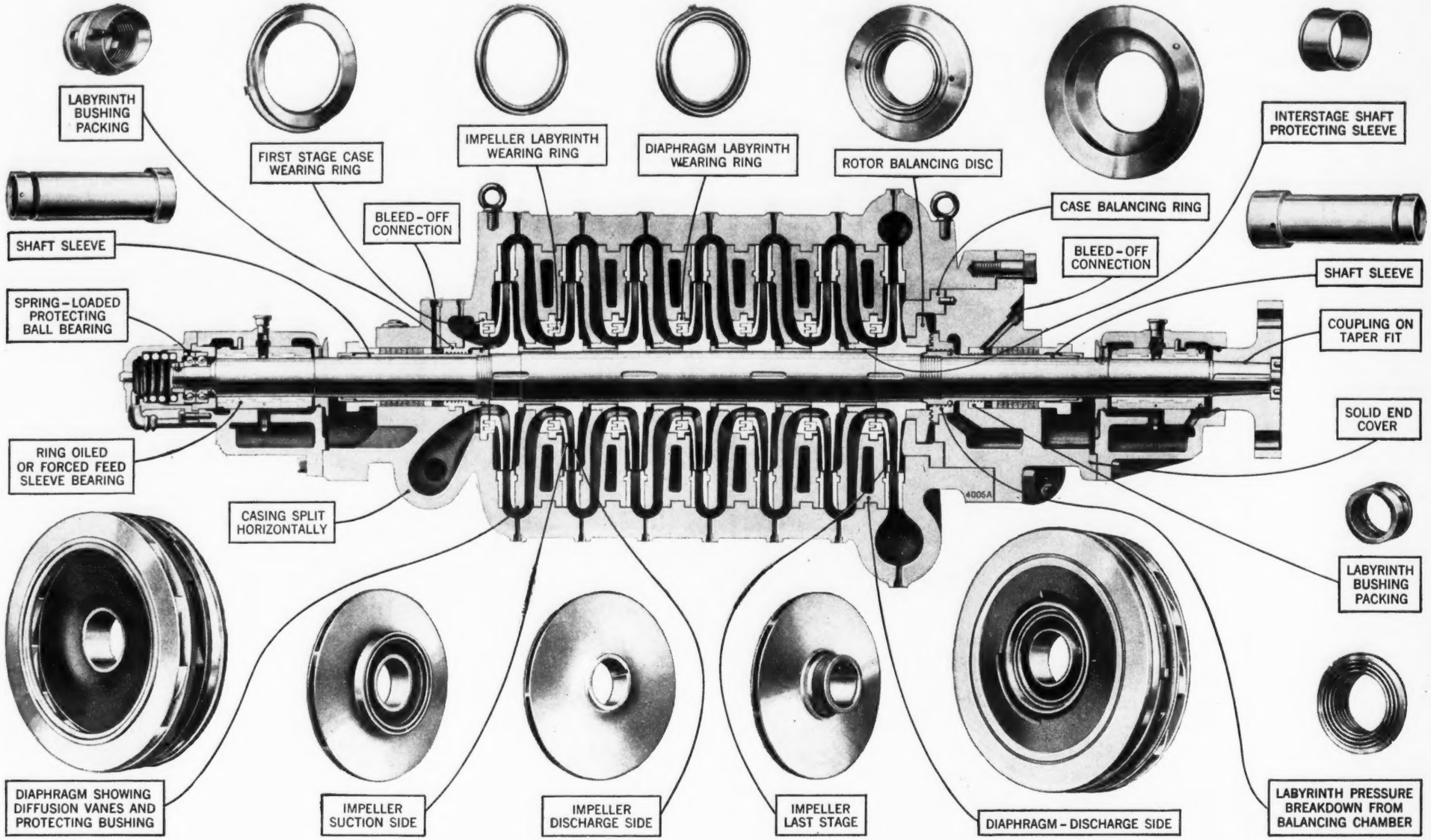
Gentlemen: Without obligation, you may send me the bulletin fully describing the W-K-M Master Scrubber for:

STEAM ____ AIR ____ GAS ____

Name _____ Company _____ Address _____ City _____ State _____

(PLEASE PRINT)



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